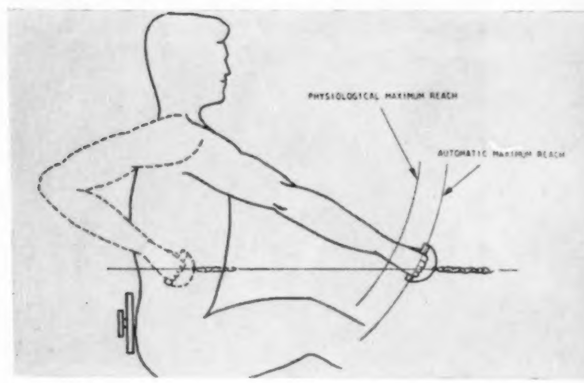
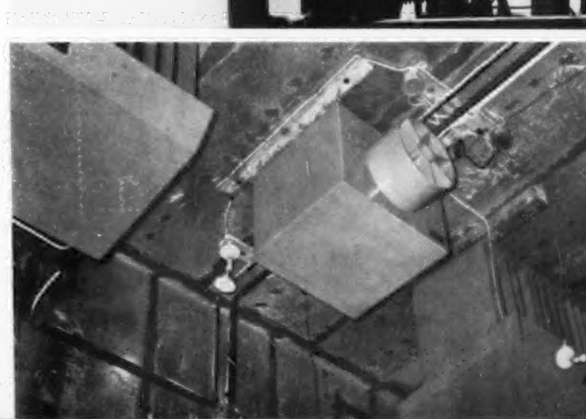
SEPTEMBER 1959

Agricultural Engineering

The Journal of the American Society of Agricultural Engineers

Engineered Control of Environments for Modern Farming





CASE HISTORIES

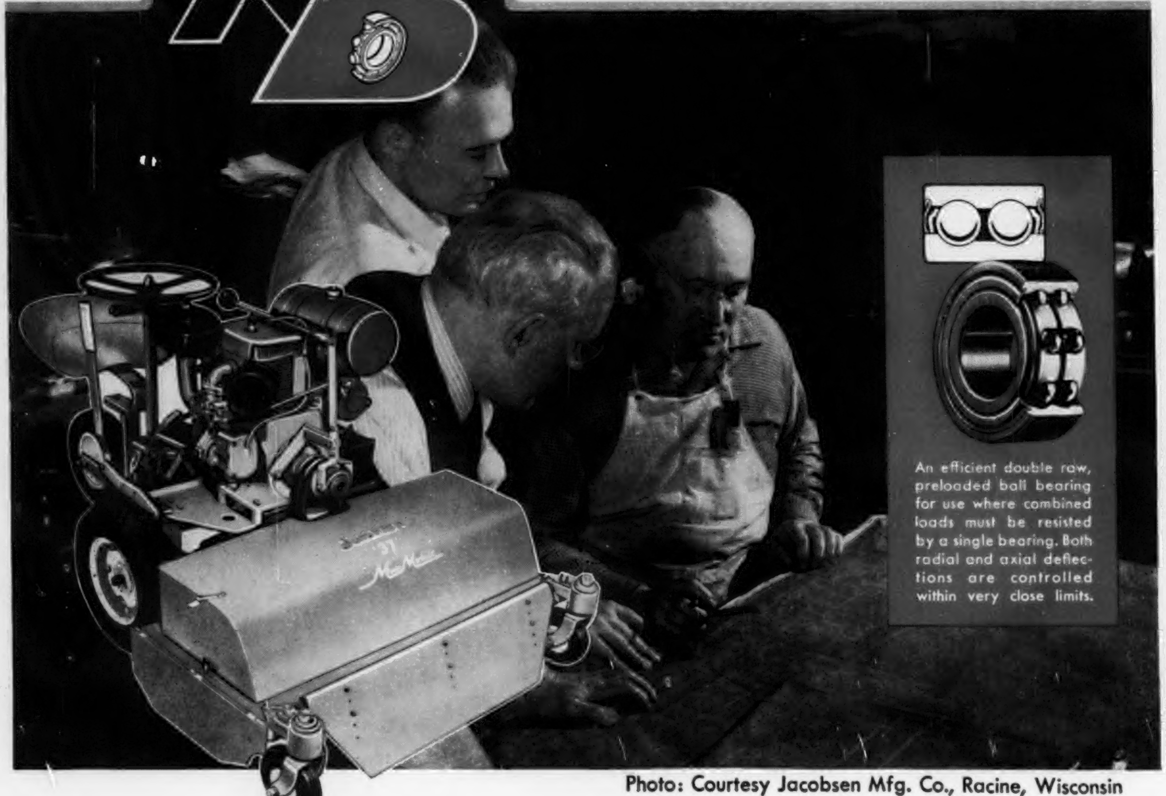


Photo: Courtesy Jacobsen Mfg. Co., Racine, Wisconsin

N/D Ball Bearing Design Helps Cut Power Mower Costs $4.29 Per Unit!

CUSTOMER PROBLEM:

Require bearing design that will help reduce production costs of power mower without affecting mower's high quality and performance.

SOLUTION:

N/D Sales Engineer, working with company engineers, recommended a new, more efficient cutter housing design utilizing three precision New Departure production double row ball bearings. These high capacity dual purpose bearings resist heavy radial and thrust loads in any combination. The conversion accounted for a parts and assembly-time cost savings of $4.29 per mower. In addition, the manufacturer is able to promise mower users years of trouble-free performance, while pricing more competitively at retail!

Perhaps there's a New Departure production ball bearing that will help lower costs and add new sales appeal to *your* product! Why not call on New Departure today? For more information write Department E-9.

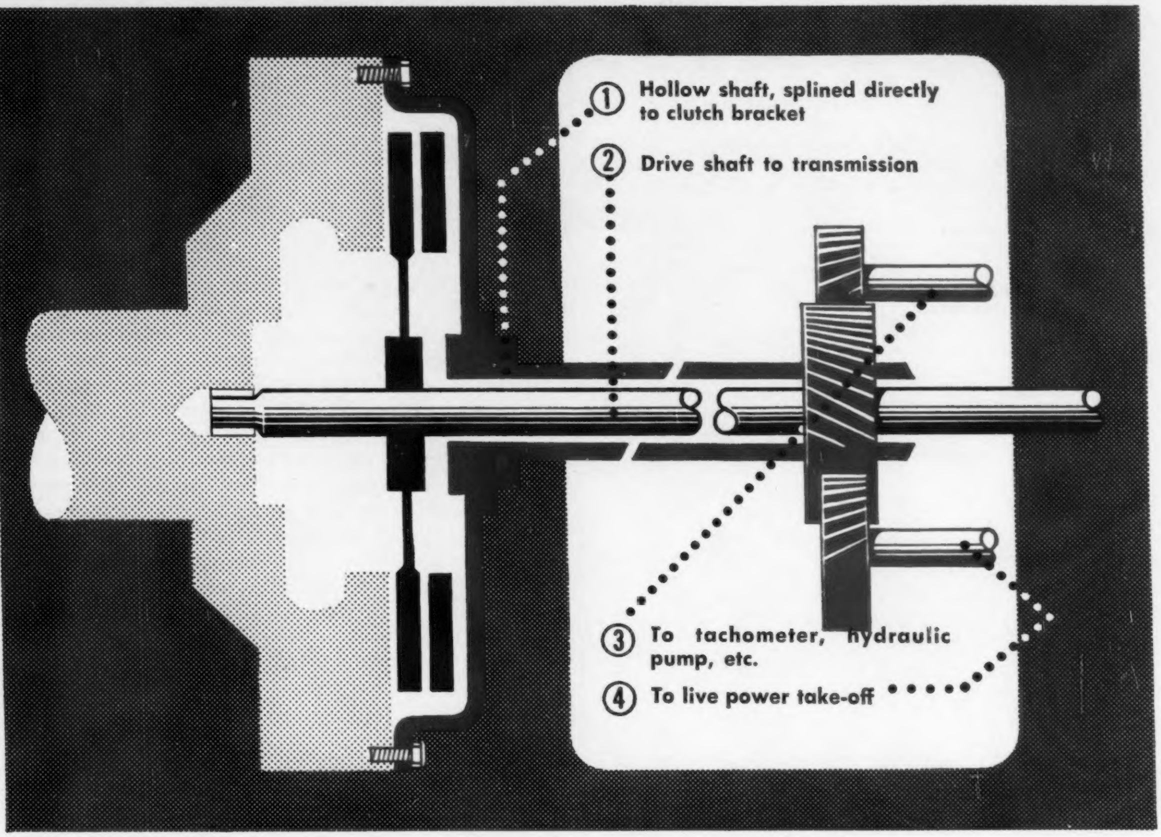
Replacement ball bearings available through United Motors System and its Independent Bearing Distributors

NEW DEPARTURE

DIVISION OF GENERAL MOTORS, BRISTOL, CONN.

NOTHING ROLLS LIKE A BALL

SPICER SPLIT-TORQUE CLUTCH provides a second and <u>continuous</u> source of take-off power



The Spicer Split-Torque Clutch delivers power to two shafts . . .

- One is the drive shaft — the same as you'll find in a conventional transmission. As usual, power is controlled by engaging and disengaging the clutch.
- The other is a concentric hollow shaft splined to the clutch bracket. Since the bracket is bolted to the flywheel, power is continuous whenever the engine is running.

AS IT'S NOW EMPLOYED by one tractor manufacturer, the concentric outer shaft provides power for a continuously operating hydraulic pump and a live PTO shaft. And, there's almost no limit to the number of accessories and PTO drives that can be powered by the Spicer Split-Torque Clutch.

In by-passing the clutch plate with a source of continuous power you make your tractor more efficient . . . more profitable . . . simpler to operate. That's why the Spicer Split-Torque Clutch is a sales feature in itself.

Investigate the advantages of the Spicer Split-Torque Clutch before you finalize your design. The Dana engineer will be glad to show you how its second source of power can be used to best advantage.

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Many of these products are manufactured in Canada by Hayes Steel Products Limited, Merritton, Ontario

Agricultural Engineering

Established 1920

CONTENTS • **SEPTEMBER, 1959** • **Vol. 40, No. 9**

AGRICULTURAL ENGINEERING is owned and published monthly by the American Society of Agricultural Engineers. Editorial, subscription and advertising departments are at the central office of the Society, 420 Main St., St. Joseph, Mich. (Telephone: YUkon 3-2700).

JAMES BASSELMAN, *Editor and Publisher*

SUBSCRIPTION PRICE: $8.00 a year, plus an extra postage charge to all countries to which the second-class postage rate does not apply; to ASAE members anywhere, $4.00 a year. This special issue $1.50 each.

POST OFFICE ENTRY: Entered as second-class matter, October 28, 1933, at the post office at Benton Harbor, Michigan, under the Act of August 24, 1912. Additional entry at St. Joseph, Michigan. Acceptance for mailing at the special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized August 11, 1921.

Engineered Environment

"ENGINEERED Control of Environments for Modern Farming" with respect to fatigue, psychology and atmosphere has been selected as the theme for this special issue of AGRICULTURAL ENGINEERING. Two articles deal with work that engineers have been doing in reducing *human stresses* and *fatigue* through an evaluation of the basic relationships of operator, seating, steering and controls in the operation of tractors and farm machines. Both articles were presented at a national meeting of ASAE during a special session on "Ergonomics in Farm Equipment Operation." One is a report of research work co-sponsored by Purdue University, Indiana Heart Foundation, American Heart Association, Indiana State Board of Health, and the National Institutes of Health aimed at finding ways to keep the farmer with heart disease on the farm, and to keep others from becoming subjected to unfavorable conditions.

Psychology in farm equipment design and farm work efficiency is covered in two articles that also were presented during the special ASAE session on ergonomics. One article covers the potential applications of psychological research, or human engineering, to mechanical design problems; the other reports on progress toward integrating the farm worker and his machine for maximum efficiency.

Controlling the *atmosphere* relative to farming is reviewed in a series of articles which represent a summary or "state of the art" report of scientific literature on the relation of plants and animals to their environments. Separate articles report on plants, poultry, dairy cattle, beef cattle, swine and sheep. Also included are articles on criteria for appraising the performance of irrigation pumping plants and a new air-conditioned helmet for tractor and farm machine operators.

As farms become larger and the number of farm workers decline environmental control will become an increasingly important factor in improving the working conditions on the farm.

Special Incentive for ASAE Membership Efforts

A SPECIAL incentive is again being offered by ASAE headquarters to members who make a special "new member" effort during October Membership Month. Each member submitting two new applications postmarked during October will receive his choice of an ASAE lapel pin or lapel button.

October has been designated as Membership Month because (1) it marks the beginning of the year's activities for most sections, (2) applications received during October can be processed in time to permit the new member to enjoy a full calendar year of services, and (3) strong membership activity at the beginning of a section's year of operation can stimulate enthusiasm for other projects and activities suited to a growing organization.

Application forms will be supplied on request to ASAE headquarters. Members are requested to enclose two new completed application forms in one envelope with a note expressing their preference—the ASAE lapel pin, or the ASAE lapel button.

Report to Readers . . .

CONTENTED COWS REPOSE IN COMFORT ON NEW FOAM PLASTIC MATTRESSES

A British ex-cavalry major has developed a foam plastic mattress that eliminates the need for straw bedding for his dairy herd, whose production is said to be more than three times the national average. . . . . The mattress consists of a solid foam plastic filling encased in a particularly thick, durable and flexible vinyl covering that withstands heat, cold, moisture and rough usage. It is 5½ feet in length, 3½ feet in width, and tapers from a thickness of 3 inches on one side to 1½ inches on the other – and weighs 7 pounds. . . . . Advantages claimed for this mattress are better health, saving in labor and cost of straw, and cleaner cows. "The cows simply love them," claims the major; "they never want to get up." Since it is said that a cow's milk yield is in direct ratio to the length of time she spends lying down, with a measurable drop for every quarter mile she walks, this could be a strong selling point for the plastic mattress.

TWO-WAY RADIO TELEPHONE MOVING INTO FARM MARKET

It is quite significant that two "new product" releases on two-way radio telephones should reach the editorial desk in the same mail, and from points as widely separated as Illinois and Connecticut. In each case the radio telephone unit is a combined radio transmitter and receiver. It can be used without an operator's examination or any license procedure on the citizen's band of radio channels, and any number of units can communicate with each other. . . . . With the extraordinary increase in the number of motorized implements, machines, and equipment of all kinds now in use – both on and off farms – and at greater distances from bases of operation, the need for prompt, efficient means of intercommunication becomes increasingly important. Indeed the potential market for two-way radio telephone equipment should prove attractive to manufacturers of such products, and one becoming ripe for exploitation.

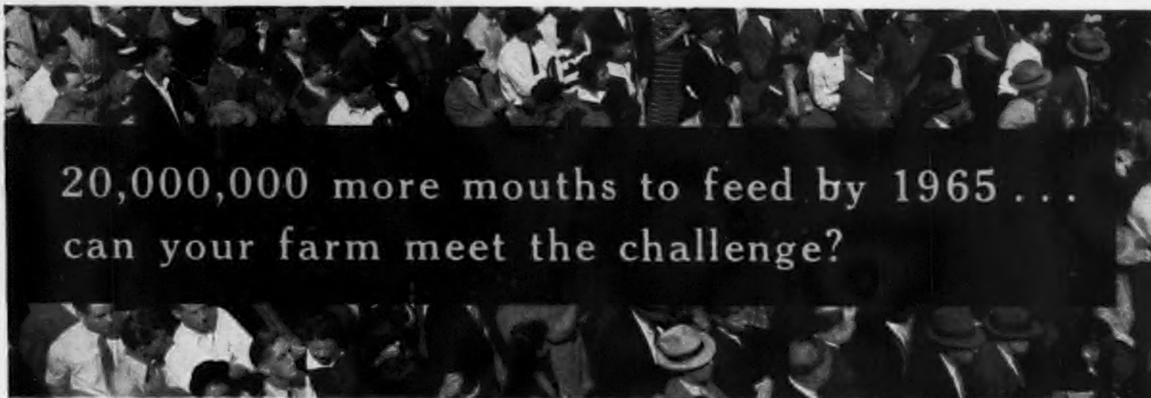
NEW DEVICE SPEEDS BAGGING OF WOOL

Since mechanization speeds up so many mechanical operations in agriculture, why not that of bagging wool? A Louisiana State University agricultural engineer asked himself that question, then proceeded to answer it by designing a machine to do the job. . . . . The standard wool bag used in Louisiana is 26 inches in diameter and 7 feet long, and in use one of these bags is attached to the end of the 24-inch cylinder of the bagging machine. Wool is then fed by hand into the cylinder and compacted in the bag by a hydraulic ram. Specially designed projections on the ram head extend into the bag packing the wool against the sides of it. . . . . The ram may be operated by an electric motor and hydraulic power pack or direct from the hydraulic system of a farm tractor. With this setup two men can pack 12 bags of wool of 225 pounds each per hour.

A RUBBER-LIKE SYNTHETIC REVEALS ASTONISHING PHYSICAL PROPERTIES

This product is urethane. A thin layer of cast urethane between two metal sleeves, it is said, will create a drive-shaft torsion elastic spring that will transmit full engine torque and yet dampen vibration and cushion shock. This same product poured into a mold will set up and form a permanent bond with any surface, providing amazing strength and abrasion resistance. . . . . Besides casting this material as a solid, it can be made into a plastic-like resilient foam. A recent application of the latter form was for filling pneumatic tires; the tires would not go flat even after being fired upon at point blank range with firearms. . . . . Another possible application for this synthetic would be for building waterproof storages or other structures quickly and at low cost by excavating cellars or pits and coating the sides and bottoms with urethane foam. Earthen pillars coated with this foam might be used to support a light-weight yet surprisingly strong, rigid foam ceiling.

(Continued on page 488)




Cat Diesel Tractors pull a 400' loop of anchor chain to cut a 75' swath through scrub growth. Another Cat track-type Tractor pushed out the big trees.

Latest population count: 173,888,000. In a scant 6 years, we'll have 20 million more people to feed and clothe — an increase far greater than the *entire* population of Canada! Beyond that, economists put our population at 225 million by 1975. To meet the challenge, your farm will be pushed to undreamed of productivity. Land improvements will play an important part in maintaining our standard of living.

Here's how one young farmer is gearing up to meet the future

He's Norris Raun, 37-year-old rice grower and cattleman of El Campo, Texas. Starting from scratch, he has carved a 5000 acre ranch out of scrub timberland. With bulldozer and determination, he cleared land, filled low spots, cut down ridges. He drilled wells, dug irrigation canals, built levees. Land that once grew only rattlesnakes makes 30 bushels of rice per acre, or carries a cow for every couple of acres. And, the ranch is still expanding.

Here's the point: this all took time. In fact, Raun has been working on land improvement for ten years, and he has more plans for the future. What he's done would take *generations* with ordinary wheel farm tractors or muscle power. That's why Raun chose Cat-built equipment. And after the ground was prepared, he found his Cat Diesel Tractor the best farm power yet — with the lowest operating costs — greatest work capacity — versatility and longest life of *all* farm tractors, whether on wheels or tracks.

If you've been thinking of improving or expanding your farm, now is the time to start it! See your Caterpillar Dealer for complete information on the equipment you'll need.
Caterpillar Tractor Co., Peoria, Illinois, U.S.A.


Tough spots were cut and filled to grade by bulldozer, or Cat Diesel Tractor and Scraper. This assures even water coverage, helps prevent drowning or burning crops.


For routine farm work, Norris Raun proves you can't beat a Cat Diesel Tractor. Here, a Cat D6 Tractor (75DBHP) pulls his home-built levee builder.

CATERPILLAR

Caterpillar and Cat are Registered Trademarks of Caterpillar Tractor Co.

PRESENTED IN THE INTEREST OF BETTER LAND USE AND SOIL CONSERVATION

. . . Report to Readers *(Continued from page 486)*

MECHANIZES HARVESTING OF SOUR CHERRY CROP

USDA and Michigan AES researchers have been saying it will be another two or three years before mechanical harvesting of sour cherries becomes an accomplished fact. However, a Michigan grower, faced early this past season with the uncertainty of getting pickers because of a short crop, decided to mechanize his harvesting operation this year. He bought one of the tree shakers used in California for harvesting nut crops, and had some frames built to catch the cherries as they fell. With this equipment he harvested his crop (from 2,000 trees) in 15 days with a 9-man crew – an operation that ordinarily would have required 120 pickers. . . . . Based on a rough estimate, this grower says that mechanical havesting cut his picking costs by at least one-half and perhaps as much as two-thirds. In a good crop year he thinks the difference would be even more, possibly a saving of as much as four-fifths of hand-harvesting costs. . . . . While bruising was about double that for hand-picked fruit, the researchers believe this difference can be offset by mechanical improvements in the catching frames. The cherries are not bruised in being snapped from their stems or in hitting limbs on the way down. With newer models of experimental catchers, there is apparently no bruising when the fruit hits the catchers, but only when it rolls from the frames into lugs or other containers. . . . . As for leaves and twigs shaken down with the cherries, their removal is a simple matter. For years this grower has been hauling his cherries to the processing plant in water, and since leaves and other debris all float, they can be easily removed.

SOIL MIXER PROMISES CHEAPER FIELD CONTROL OF NEMATODES

A new farm machine, developed by a British scientist, points the way to cheaper control of nematodes and possibly of other soil-borne diseases. It is said that this soil mixer, with a single application of yellow mercuric oxide, can reduce the golden nematode population of a field by 60 to 80 percent, at a cost of around $30 an acre. In tests of this method of control, potato yields have increased by over two tons per acre. . . . . In developing this soil mixer, the basic components of two machines – rotary tiller and duster – were used. For surface application, the dust is deflected by the duster through transparent plastic tubes onto the soil surface. For an application below the soil surface, the dust is blown through tubes which open into spaces left behind duckfoot tines clamped to a tool bar in front of the rotary tiller. The duster is operated by the exhaust from the tractor, and the pesticide is mixed with the soil by the rotary tiller which will work to a depth of 9 inches.

STEAM-DRIVEN POWER UNIT MAKES BID FOR ATTENTION

Nostalgic memories of those of riper years who grew up on the farm in the horse-and-buggy days may be readily rekindled by any hint of a possible revival in the use of steam power. But it is not at all likely, in the light of foreseeable developments, that the steam engine will ever seriously compete with the internal-combustion engine and the electric motor as a farm power unit. There are, however, limited-access areas, as well as other possible conditions, in which the two latter prime movers may not so well meet power requirements on account of excessive costs and other limiting factors. In such cases steam power may provide the best answer. . . . . The announcement of development of a steam-power unit by an English manufacturer for just such a market is therefore of interest. This company builds a portable unit weighing under 3,000 pounds which develops its normal rated output of 5 to 6 hp at 450 rpm, and is capable of an intermittent overload of 7 to 8 hp. Most fuels ranging from low-grade coal or lignite and wood to cotton waste and other local-grown combustible materials can be used. Operating on the controlled-flow and monotube principle, the danger of explosion in the steam generator is considerably diminished. Besides fuel, little or no operating cost should be involved with such a unit. The potential market for it, though scattered, might well prove an attractive one.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A new approach to hydraulic controls! Here's a break-through that is the answer for a lot of equipment—maybe yours!
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National O-Rings are precision made, uniform commercial rings available throughout the United States—promptly! Quality is superior; all ingredients are inspected before compounding and compounding is strictly controlled for maximum uniformity. Molding is done on modern equipment by veterans of 20 years in O-Ring manufacture. Every precaution is taken to insure that no O-Rings with cuts, scratches or mold defects are shipped.

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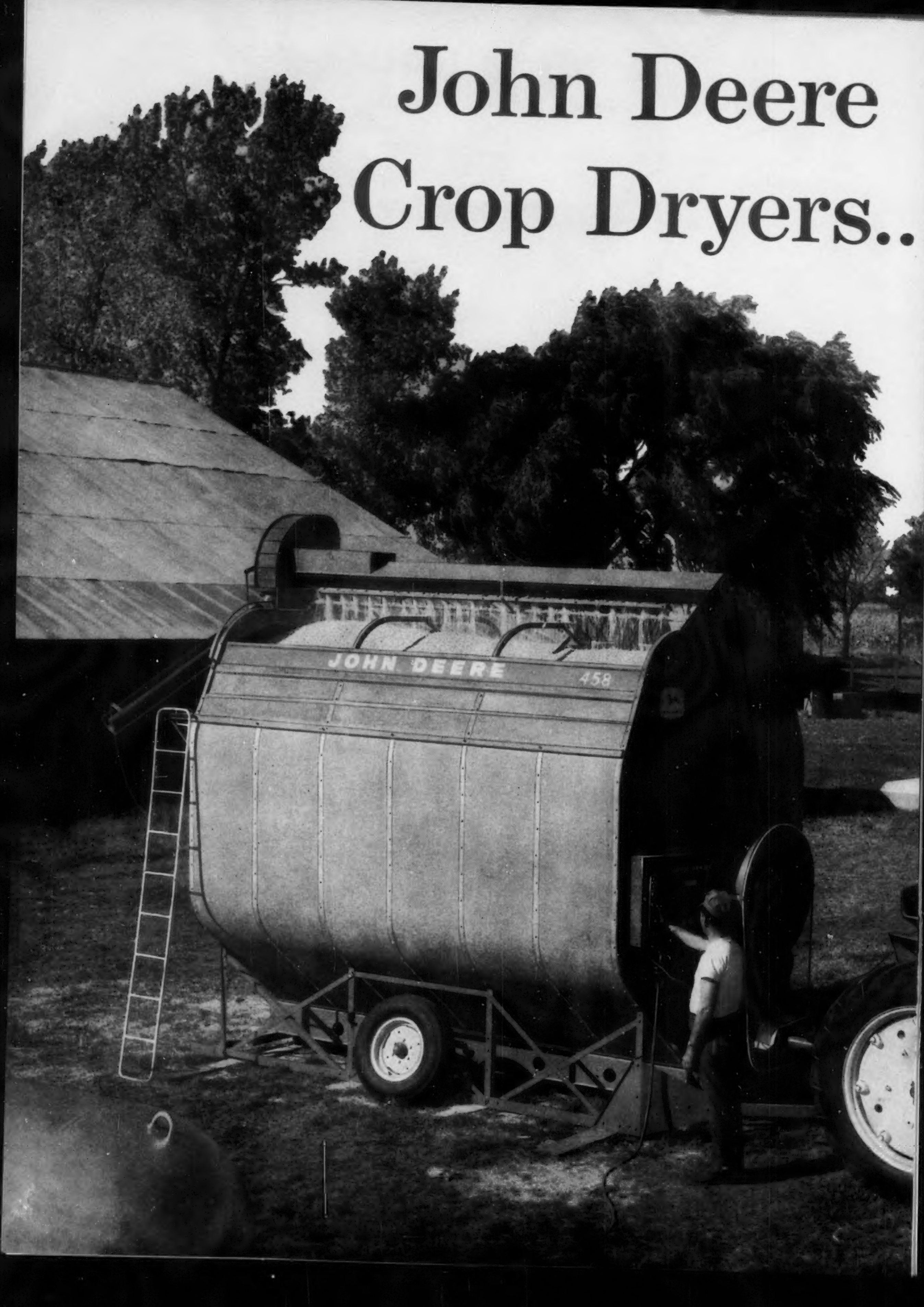
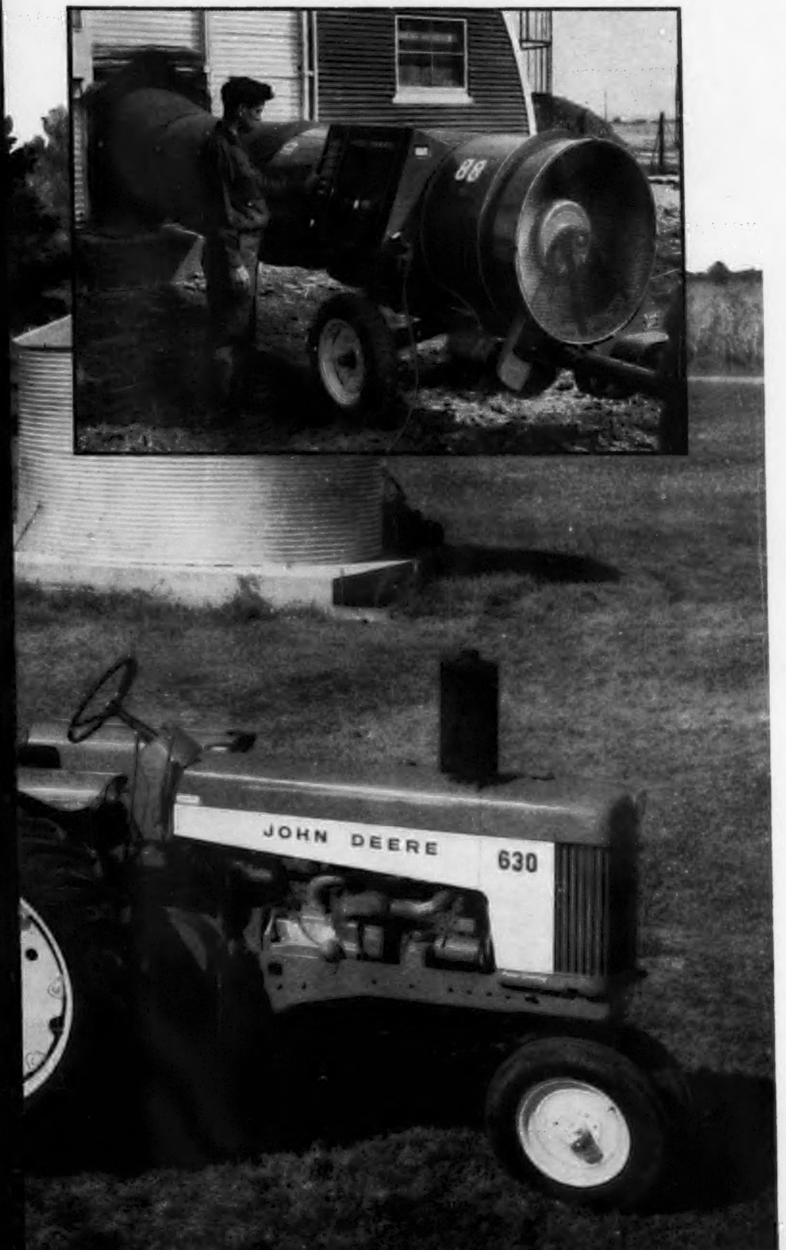
John Deere Crop Dryers...



they pave the way to bigger harvest profits, bigger dealer volume

John Deere dealers can now match the drying needs of all customers with either the batch-type 458 Grain Dryer, or the versatile new 88 Portable Crop Dryer.



Every farmer wants to "make hay while the sun shines." The same principle applies to all crops. John Deere Crop Dryers permit an earlier, easier, surer harvest at high moisture content. They take away risk, discomfort, and loss from harvest . . . add security, convenience, and profit. More and more farmers are coming to realize that a dryer is not just emergency equipment for a wet year, but a vital part of modern harvest equipment.

For Example . . .

Wheat farmers can go into standing wheat of 20 per cent moisture and combine just the heads, avoiding lodging, shattering, hail damage, and the need for windrowing.

Hay growers can bale green, leafy hay at 45 per cent moisture . . . be sure of quality hay with more protein content.

Corn growers can harvest two weeks early, at 25 to 30 per cent moisture . . . streamline operations by field-shelling. Grain sorghum can be combined at moisture up to 26 per cent to reduce field loss.

Permit System Sales

These are the first crop dryers to be made by any full-line implement company. They set new standards of safety, convenience, and efficiency . . . open up new opportunities for dealers to sell complete harvesting and materials-handling systems.

They are just one more reason why the John Deere franchise is the most valued in the farm equipment field.

"Wherever Crops Grow, There's a Growing Demand for John Deere Farm Equipment"

JOHN DEERE
MOLINE, ILLINOIS

JOHN DEERE

HOME-MADE TREE DIGGER DOES WORK OF 40 MEN!

This ingenious home-made tree digger saves much time and labor on the 800-acre tract of the Onarga Nursery Co., Onarga, Ill.

Easily doing the work of 40 men, it can dig up 60-70 shade trees an hour, roots and all, as easily as a soda fountain clerk scoops up a ball of ice cream!

That's John Haworth at the controls. Others left to right are J. M. Snyder, Francis Albee, Texaco Consignee (partly hidden), C. C. Lewis, foreman and A. L. Fisher, treasurer of the company. The Onarga management, like farmers everywhere who operate power equipment, knows that *it pays to farm with Texaco products.*

Marfak prevents bearing breakdowns

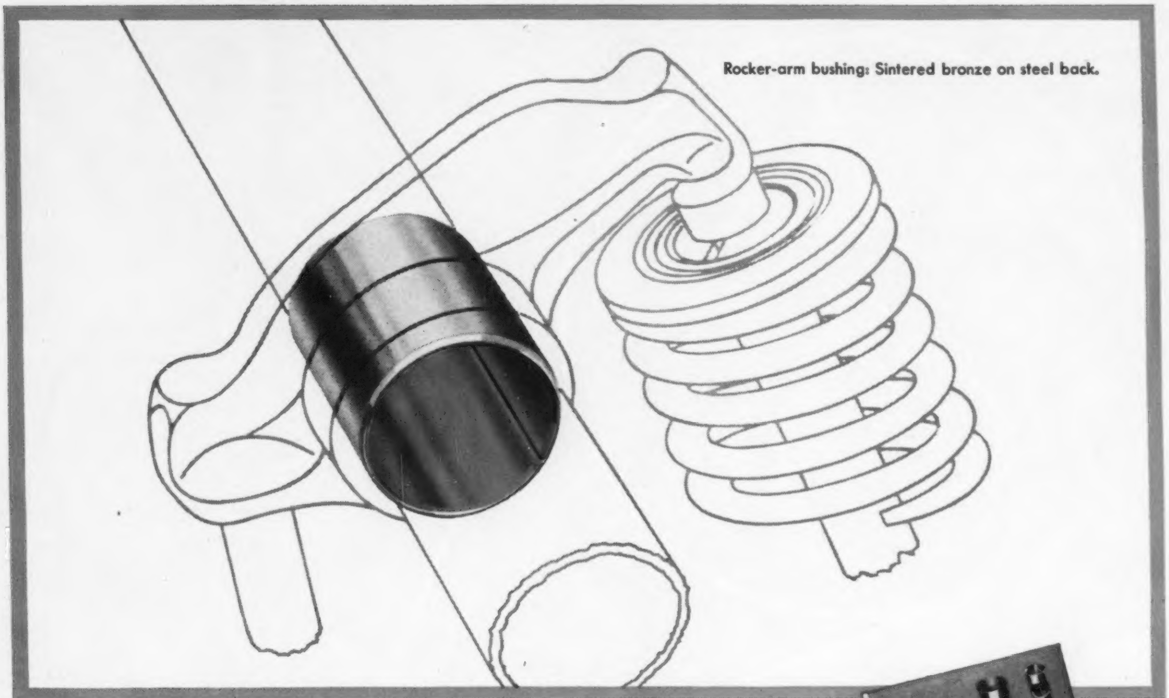
J. V. O'Banion (left) operates a dairy farm with a herd of registered Guernseys near Campbellsville, Ky. Not to be outdone, his wife takes care of 1,100 laying hens. Mr. O'Banion agrees with L. T. Wheat, manager of the Heber Lewis Oil Co., that field breakdowns are avoided with Texaco Marfak lubricant. It forms a tough collar around open bearings, sealing out dirt and moisture. Marfak won't drip out, wash out, dry out, or cake up. Farmers everywhere who try it, continue to *buy* it.

BUY THE BEST...BUY TEXACO

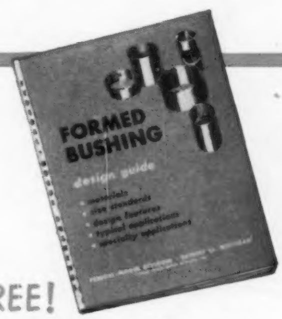
Carrying the rocker-arm load . . .

FORMED BUSHINGS

SAVE SPACE—SAVE WEIGHT—SAVE COST!



Rocker-arm bushing: Sintered bronze on steel back.



Here's a typical application in which the design engineer uses formed bushings to meet both performance and cost demands.

This rocker-arm bushing is formed from sintered bronze-on-steel strip. In fast oscillation, at 200 p.s.i. average loading, it has an average life of 5,000 hours, or 150,000 miles. Cost-wise, you will find it attractive. Space and weight are saved, with no sacrifice of strength or service life.

There are countless other applications in motor, machine and accessory design, where formed bushings deliver equal satisfaction. Let our engineers assist you. Consultation is free—no obligation.

FREE!

Bushing Design Guide, technical publication by our Engineering Department. Shows materials, size standards, design and application features. Write today!

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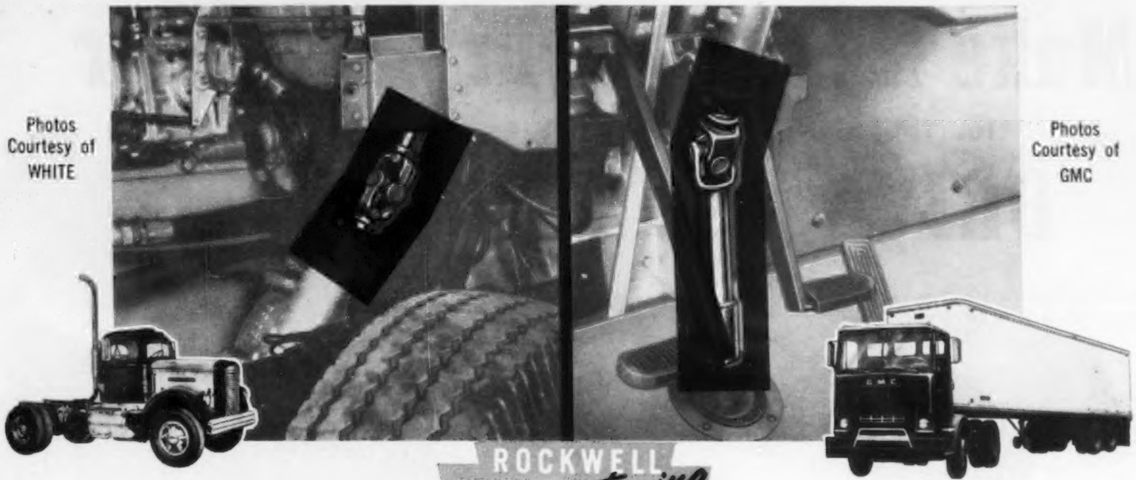
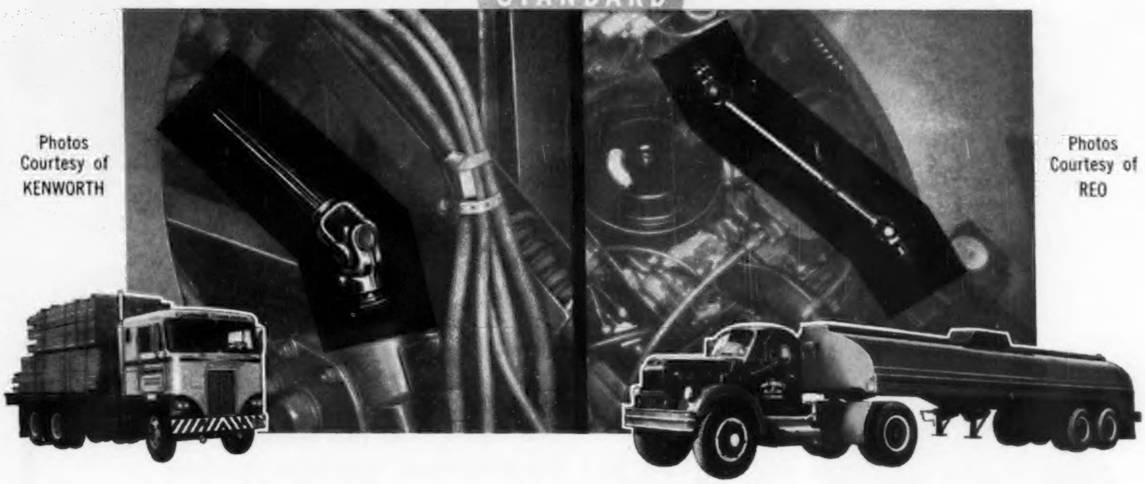


ROCKWELL STANDARD

To "take power steering around corners" rely on the Keystone of Quality...

Photos Courtesy of KENWORTH

Photos Courtesy of REO



...select BLOOD BROTHERS Jointed Steering Shafts

On power steering assemblies for famous-make trucks, Blood Brothers Universal Joints "take power around corners" smoothly and dependably. They're widely used on manual steering assemblies too . . . for road-building and construction machines, farm tractors and self-propelled implements.

When you need universal joints to "take power around corners" — or provide for drive shaft flexibility — be sure to consult Rockwell-Standard. Our engineers will gladly assist you . . . and their experience may save money on your project.

K-1C

L6S, L6N

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Blood Brothers Universal Joints

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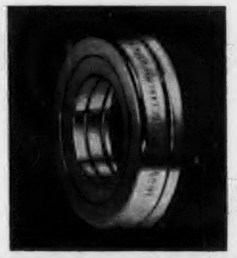
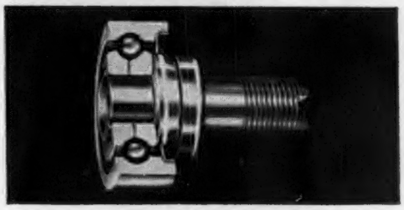
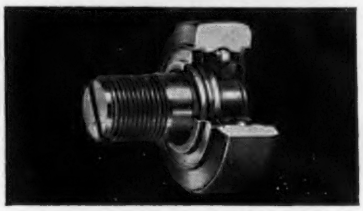


Clutch Bearings

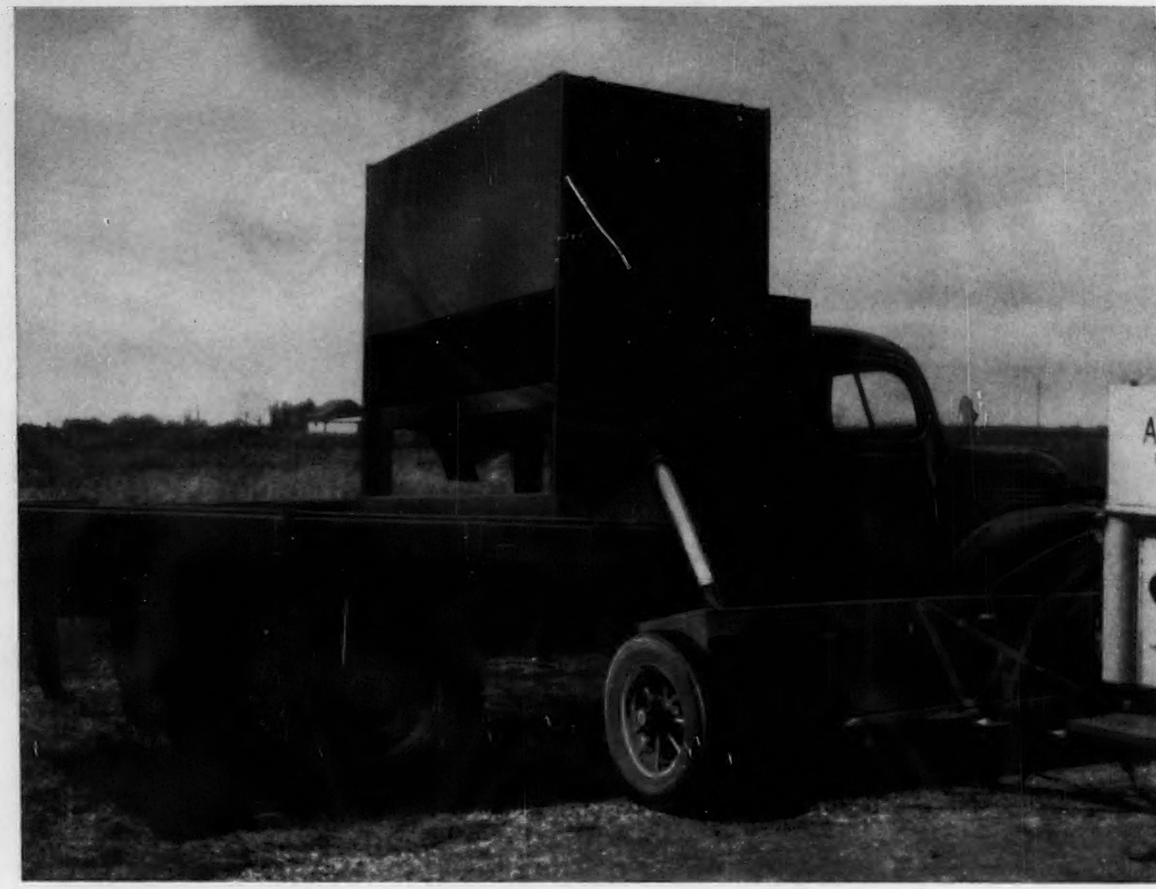


Hay Rake Bearings

Idler Pulley Assemblies



Plunger Rollers



Honeywell electronic panel controls grain aeration AUTOMATICALLY

Red light: fan operating. Amber light: manual control. Green light: automatic. Honeywell's new grain storage Aeration Panel (right) provides switch for completely automatic control or manual operation.

Recent government research has shown that with proper aeration, stored grain is completely safe from danger of rot, mold and other types of spoilage. Honeywell now offers this panel to give you proper aeration, plus the convenience of centralized, completely automatic control of the aeration process.

The Honeywell Aeration Panel eliminates difficult grain turning. It provides temperature and humidity limit controls to insure fan circulation of air through the grain *only* when proper outside conditions exist. In addition to these easy-to-set temperature and humidity controls, an accurate timing device provides a handy timed manual control period.

With a Honeywell Aeration Panel, your grain will be stored in absolute safety. You'll be able to wait for top-dollar prices without any worry of grain spoilage or loss due to rot or molding. Fill in this coupon and send today for a free brochure giving additional information.

Honeywell

H HONEYWELL *First in Control*

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Please send me your free brochure on Honeywell's new Grain Aeration Panel.

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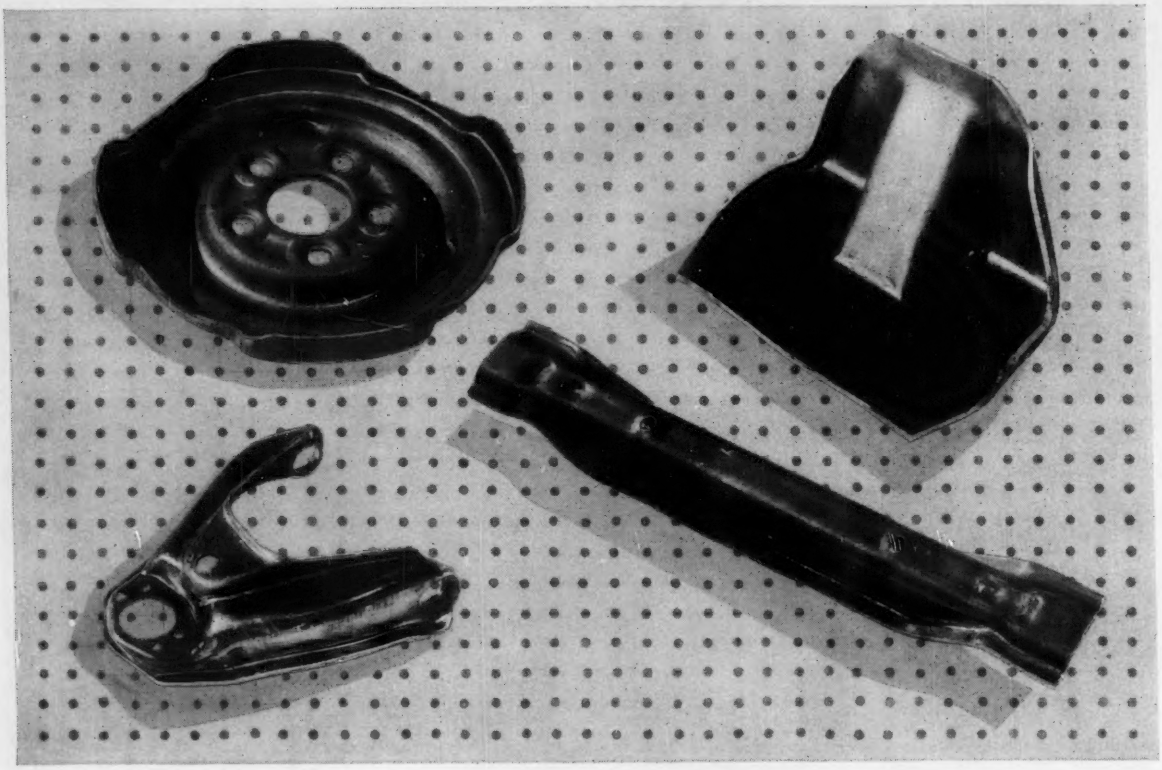
*CITY*__________ *STATE*__________



Agricultural Engineering

September 1959
Number 9
Volume 40

James Basselman, Editor

Summary Report of the

POWER AND MACHINERY DIVISION

C. B. RICHEY
1958-59 Chairman, Power and Machinery Division

THE Power and Machinery Division is the largest technical division in the American Society of Agricultural Engineers, since nearly 50 percent of the members indicate that their major interest is in this field. As would be expected, a greater percentage of the members are in the North Central area of the United States than is the case with the other Society divisions, since most of the manufacturing is done in this area.

Steering Committee

The Steering Committee of the Division has the following major responsibilities:

1 Collect and assemble program suggestions for use by the Division chairman in arranging programs for the two annual meetings.

2 Elect from its membership a program vice-chairman who will normally advance to steering committee chairman, division vice-chairman and finally division chairman, each of these being subsequent one-year terms. This arrangement assures that the division chairman has adequate familiarity and experience with division affairs and policies when he enters the office.

3 Review division committee activities, suggest committee personnel and advise and assist the division chairman in forming new committees.

The Steering Committee is composed of representatives from the various geographical Sections of ASAE, the number of representatives from a given section varying somewhat according to the number of P & M preference members in that section.

The present Steering Committee system was inaugurated in 1956 during the presidency of Wayne W. Worthington and it has been very effective in improving program quality and division activity. Last winter over 100 program suggestions were collected by Program Vice-Chairman Arnold B. Skromme. In view of this wealth of material, the Steering Committee suggested that a greater percentage of it be utilized by holding two concurrent Power and Machinery programs. This was successfully done at Cornell University during the 52nd Annual Meeting of ASAE in June and will also be done during the Winter Meeting at Chicago in December, reports H. F. Miller, 1959-1960 Chairman of the Division.

Professor K. K. Barnes of Iowa State College was chairman of the Steering Committee during 1958-59. He advances to division vice-chairman this year and is being succeeded by Arnold B. Skromme, chief product engineer of the John Deere Spreader Works at East Moline, Ill.

Technical Committee

The Technical Committee has the responsibility for developing and recommending approval of various standards in the power and machinery field. During the past year it has approved a new standard for free-link three-point hitches. Currently, studies are being made of farm tractor controls, service recommendations for tractors and implements, and V-belt drives. L. H. Hodges, works manager, Rockford Works, J. I. Case Company, is chairman of this committee. The membership is primarily composed of responsible engineers from the farm equipment industry and at least four public service representatives.

Committee on Fertilizer Application

Members of the Committee on Fertilizer Application are also ASAE representatives on the National Joint Committee on Fertilizer Application (ASA, ASHS, NCA, NPFI, FEI and ASAE cooperating). This committee, under the leadership of Walter C. Hulburt, AERD, ARS, USDA, hosted the National Joint Committee Meeting, held with the ASAE Annual Meeting at Cornell, and arranged a half-day fertilizer session on the power and machinery program.

This committee has periodically conducted surveys of special fertilizer application machines and devices for research and issued reports covering the survey, the last being published in 1956 by the National Plant Food Institute.

Committee on Soil Compaction

The Committee on Soil Compaction, under the leadership of Chairman T. W. Edminster of the Soil and Water Research Branch, USDA, was formed to exchange research information in this field and to point out areas needing additional research.

It has developed "Definitions of Soil Conditions" and "Definitions of Tillage Operations and Equipment" in cooperation with the Soil Science Society of America. It has also reported the 1958 status of soil compaction research in the United States and Canada. The above material is published in the 1958 Transactions of the ASAE. It has recently prepared an "Annotated Bibliography on Soil Compaction" which has been published earlier this year and is available from ASAE headquarters.

This committee also arranged a half-day program for the ASAE 1959 Annual Meeting dealing with various phases of soil compaction.

Committee on Agricultural Chemical Application

The Committee on Agricultural Chemical Applications was formed in 1958 to exchange and disseminate information in this rapidly growing and changing field. It is composed of public service representatives who are engaged in research or other work involving agricultural chemicals and representatives of chemical concerns and concerns making chemical application equipment. It includes much of the interest, activity, and membership of the former Committee on Agricultural Aviation.

The committee arranged a half-day session dealing with the agricultural chemical field for the 1958 Winter Meeting and will have this responsibility again this December.

Under the leadership of Chairman Merrill Adams of the Shell Development Corp., Modesto, Calif., and Secretary Clarence Hansen of Michigan State University, the committee has stimulated interest and activity in a field of increasing importance to agriculture and agricultural engineers.

Committee on Hay Pelleting

The Committee on Hay Pelleting was formed in 1958 to exchange information on field hay pelleting problems, point out areas of needed research and to develop needed standards, such as for determining hay pellet characteristics. It is composed primarily of public service representatives engaged in pelleting research and industry representatives engaged in development of field hay pelleters. Professor H. D. Bruhn of the University of Wisconsin, a pioneer in this field, is chairman. *(Continued on page 558)*

Editor's Note: In order to make better known the activities of the various divisions of ASAE the outgoing chairman of each division has been invited to submit a summary report covering the division's accomplishments during his year as chairman. A summary report of the Soil and Water Division appeared in the August issue of AGRICULTURAL ENGINEERING.

Effect of Tractor Operation on Human Stresses

Heinrich Dupuis

(Translated from the German by Hans W. Sack, Member, ASAE)

The basic relationships of operator, seating, and controls and their importance to automotive designers

OPERATING a motor vehicle imposes definite levels of physical and mental performance (stresses) upon the operator. If the operator's controls are not properly adapted to his anatomy, the performance demanded of him may quickly reach and even exceed the limits of tolerance. As a result of excessive stress, premature fatigue and impaired health, the possibility of accidents will increase. Such human stress will increase with the higher speeds of today's vehicles, and even more so in the case of agricultural tractors considering the additional effort required for operating mounted implements. Therefore, great emphasis must necessarily be placed on adapting the operating controls to the physical needs of the human operator. The optimal design, considering the operating control layout, *i.e.*, of seat and controls, may be achieved only if the physiological and psychological prerequisites are known and have been harmoniously integrated with other technical features of the design.

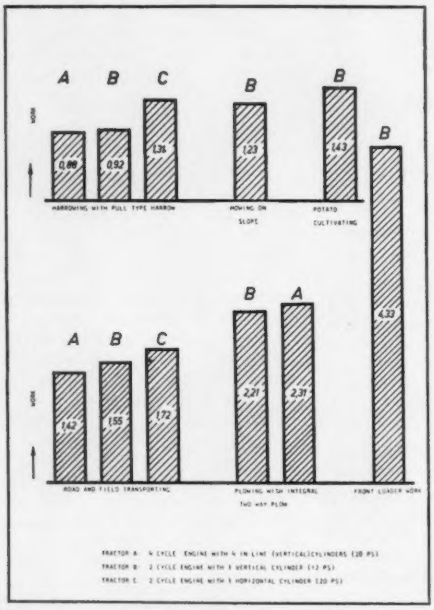


Fig. 1 Energy output of tractor operator operating three different types of tractors at different farm jobs

Paper presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1957, on a program on the theme, "Ergonomics in Farm Equipment Operation," arranged by the Power and Machinery Division. Contributed as a report from the Institute für Landwirtschaftliche Arbeitswissenschaft und Landtechnik of the Max Planck Society for the Advancement of Science, Bad Kreutznach, and the Max Planck Institute für Arbeitsphysiologie, Dortmund, German Federal Republic. Published by permission of the copyright owner, Franckh'sche Verlagshandlung, Stuttgart, German Federal Republic.

The author — HEINRICH DUPUIS — is associated with the Max Planck Institute for Farm Work and Agricultural Engineering, German Federal Republic.

Total Strain on Operator

In order that the factors contributing to the stress imposed upon a tractor operator may be analyzed, as is done in the latter part of this paper, the nature and extent of these stresses must first be examined. Subsequently, the investigation proceeds to determine the design factors which result in increased operator comfort. Although human stress was measured with operators of farm tractors as subjects, the investigation of details, such as foot pedals and hand levers, can be equally applied to all motor vehicles.

When driving the tractor, the only measurements which could be taken were physiological. Measurements of stress on the nervous system were taken in the laboratory with test subjects. Physical stress was measured by the respiration and the heart-beat methods. The first method evaluates quite exactly the amount of physical labor, that is, the energy output of the human subject in terms of work (kilocalories) per minute. The frequency of the heart beat (pulse) is a measure for evaluating uncomfortable static muscle load, greater body tension, and the resulting physical fatigue.

Figs. 1 and 2 show the results of respiration measurements of tractor operators when operating different types of tractors at several farm jobs, in comparison with other occupations. Fig. 1 indicates that, in spite of the sitting position of the tractor operator, which leads to the general opinion that operating a tractor is an easy job, the energy consumption in some phases is high. Harrowing, which requires the operator to use only the steering wheel, imposes a physical stress, as measured in calories, equivalent to that of driving a passenger car. This is shown in Fig. 2. On the other hand, there is great nervous stress.

All other tractor jobs were found to be more severe on the operator. Operating a tractor with a front-mounted loader, when judged by calorie consumption, is very heavy work, which approaches the permissible limit of human performance. Surprisingly enough, cutting logs and carrying sacks are no more strenuous. Additional proof of these statements are the measurements taken of the heart rate at these jobs.

In Fig. 3, the respective curves show that, when performing this work, the pulse increases to a point higher than 120 beats per minute. This fact can be explained by both the energy output required of the tractor operator and the extraordinary tension on the entire human body. All muscles are under a constant stress, or "preload," resulting from the repetitious operation of the many tractor and loader controls which leads to highly fatiguing static muscle

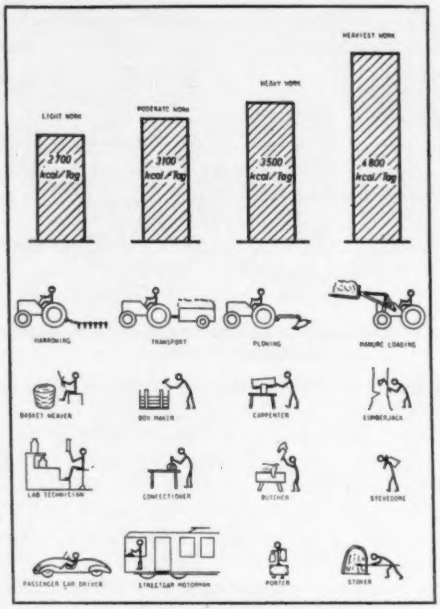


Fig. 2(a) Severity of operating a tractor compared with other occupations

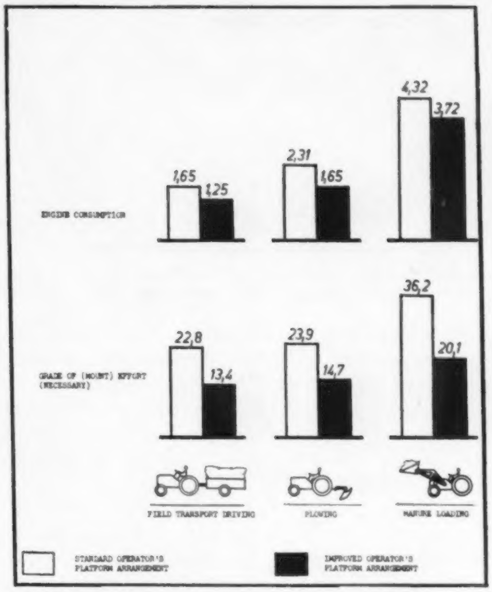


Fig. 2(b) Efficient arrangement of operator platform for easier work

strain. This is by no means surprising when it is realized that in one hour, the operator was required to shift gears and operate the clutch 230 times, operate the brake 100 times and the hydraulic control of the front-mounted loader 250 times. The physical strain upon operators of bulldozers and other earthmoving and construction equipment will be approximately as great.

Such an example shows the imperative need of making operation easier and less strenuous, with an increased measure of comfort, and thereby reduce the hazards deriving from operator fatigue. Furthermore, it is enlightening to discuss the fact, as shown in Fig. 1, that different types of tractors operating under otherwise identical conditions, that is, same type of farm work, same travel speeds, same driver, etc., impose greatly differing degrees of stress upon the operator. For instance, harrowing with the tractor designated Model C, which is one of three tractors used in these tests, is 50 percent more severe than the same job undertaken with Model A. The findings are similar for other farm tractor jobs. In all fairness, the operator of Model C tractor should be paid more to compensate for the higher stresses to which he is subjected. Any purchaser who has driven several different types of tractors will probably select the one which he finds easiest to operate.

The reasons for the differences in the total stress on the tractor operator are discussed in the sections of this paper dealing with locations of controls, body position and seating.

Location of Controls and Forces Necessary for Operation

Foot Brakes. In all of the tractors studied, the brakes, operated by foot pedal, served also as steering brakes, and frequently as a substitute for a differential lock. The first requirement for accident prevention is that brakes operate quickly and easily, that their operation requires no conscious selection on the part of the tractor operator, and that high deceleration results from relatively light pedal pressure. As to the second requirement, *i.e.*, serving as steering brakes, it is important that operating forces be kept small, since usually one drivewheel must be completely held against turning, and under many field conditions, steering brakes are used frequently.

The greatest convenience to the operator results from locating the brake pedals directly in front of the normal foot position. (In accordance with the generally accepted practice in the operation of motor vehicles, tractor brake pedals are usually operated with the right foot.) When judged in terms with the most effective application of force, the position of the brake pedals must follow well-known mechanical laws. In the force diagram shown in Fig. 4, it will be seen that, if the axis of rotation of the brake pedal does not lie along the axis of the operator's body, there will be a wasted component, p_v, of the operating force, p, which increases with the distance between the brake pedal and the symmetrical plane of the operator's body. Con-

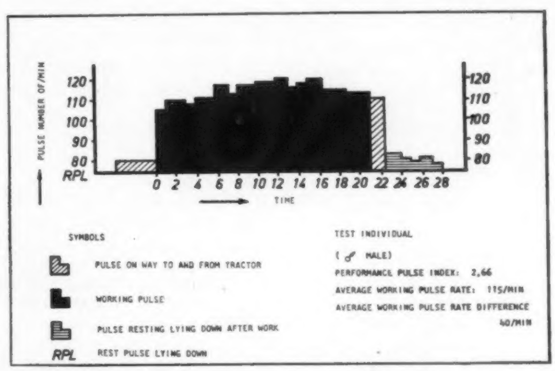


Fig. 3 Pulse rate of tractor operator operating a front-mounted manure loader

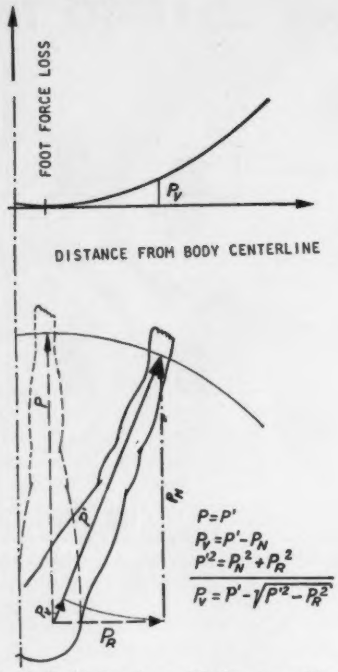


Fig. 4 Reduction in pedal thrust resulting from unfavorable location (determined geometrically)

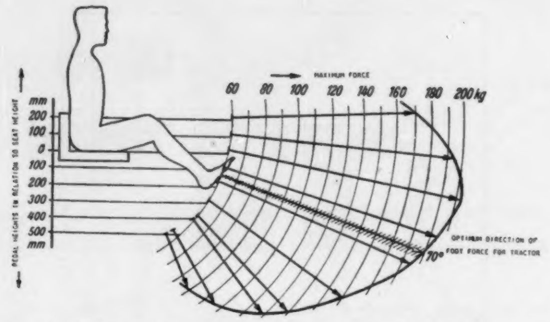


Fig. 5 Relationship of maximum pedal thrust to height of seat above pedal

sidered physiologically, pushing one leg or foot sidewise against a heavy resistance is very unfavorable.

As a result of thorough investigation, the most suitable pedal position, in relation to the symmetrical plane of the operator's body, was carefully and exactly determined dimensionally (1)*. The force necessary to operate the brake is strongly influenced by the difference in height between the pedal and the seat, as well as the distance from the pedal to the backrest. This was thoroughly investigated in 1936 by E. A. Müller (8) in connection with the operation of a horse-drawn grass mower, as shown in Fig. 5, and by Rauh (9) in 1937. The results of both investigations show that the available operating force decreases as the pedal is lowered with respect to the operator's seat. In an extremely low position, the force is equal only to the weight of the operator's leg, since there is no additional backing. As in the case with all forces applied to parts of the human body, any pressure transmitted through the leg has to be "backed up" somewhere. Usually this is accomplished with a backrest to the seat equalling the height of the pelvis. "Backing-up" forces applied by the operator's foot with a backrest striking him above the top of the pelvis are difficult and exhausting, since the spine has to be held rigid in order to effect proper backing. From the point of view of foot-pedal operation, it is sufficient to have a backrest approximately 9½ in. high above the seat, which extends upward approximately to the third vertebra.

Rauh, therefore, proposes an improved position for the foot pedal of grass mowers, as shown in Fig. 6. This compares with a previous design as shown in Fig. 6 (left), which, in light of today's knowledge, is still physiologically unfavorable, as the knee angle is too great. As most tractor operators sit upright, foot pedals should not be located at the same height as the seat, otherwise their operation results in severe tension in the tendons and ligaments surrounding the hip joints. It is much better to locate the pedal in such a way that their operating force is directed downward at a slight angle. Such conditions can be obtained by placing the pedal from 3½ to 6½ in. below the surface of the seat, and (for a person approximately 5 ft 8 in. tall) approximately 37 in. forward of the backrest, as shown in Fig. 11.

According to Müller's investigation (8), it is necessary that the distance between the backrest and the pedal be such that the leg angles slightly at the knee. Between this position and the one in which the leg is stretched out completely (knee straight), there should be a distance of 3¼ to 4 in. Were the leg bent further, the maximum possible force which can be exerted by the operator will be reduced and the leg subjected to fatigue. Operating forces applied against the brake were measured on three different tractors, and clearly show the importance of locating the pedals in what is physiologically the most favorable position. The vehicles so tested were not new, but had been in service for a considerable time. The brakes of these vehicles had been given the usual maintenance care.

*Numbers in parentheses refer to the appended references.

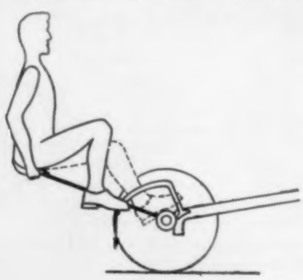
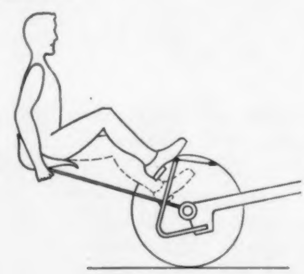


Fig. 6 *(Left)* Usual pedal location with unfavorable direction of thrust and leg position. *(Right)* Favorable direction of thrust but with knee bent too sharply



The pedal-operating forces were measured and deceleration determined by means of a Siemens decelerometer. The tractor speed before braking was measured in accordance with the German industrial standard (DIN) No. 9605, proposed by Dr. R. Franke and Dipl. Ing. Arthur Kliefoth, both of the Marburg (official) tractor testing station. Tests were conducted on the same level, dry, blacktop runway. As an interesting sidelight, similar brake tests were conducted with passenger cars and motor trucks. Some of the values so determined are shown in Table 1. (Data pertaining to only a few tractors, a single small panel truck and a 5-ton truck are included.)

Foot-pedal forces ranging from 175 to 220 lbs, which have been found necessary in some instances for operating tractor brakes, must be regarded as much too high. From the physiological viewpoint, no human being should regularly be subjected to forces greater than 77 lb, with maximum values not in excess of 88 lb, with the brake pedal properly located. Only in cases of emergency, when the deceleration must be much greater than the values shown, should the force applied against the brake pedal be higher. No pedal force greater than 77 lb should be necessary to provide the mean legal deceleration for motor vehicles, which is 5 ft per second per second for tractors having a top speed less than 12½ mph, and 8⅓ ft per second per second for motor vehicles with a top speed exceeding 12½ mph. Decelerations listed in Table 1 are maximum values. Mean deceleration values are consequently lower.

The two trucks required foot-pedal pressures below the stated limits to secure sufficient deceleration. This means that, when applying brakes, the drivers of these vehicles are subjected to less strain than are tractor drivers under the same condition. This is significant when one considers that on many farms, tractors are frequently operated by women and children. Under certain conditions, such operators (women and children) are unable to stop the tractor fast enough, especially when pulling a trailer with poor brakes. First and foremost, women and children should never be subjected to excessive physical strains.

TABLE 1. BRAKE PEDAL FORCES AND RESULTING VEHICLE DECELERATION

Vehicle	Speed before braking, km/hr	Maximum deceleration meters/sec/sec	Pedal force lb
Tractor "A" — 28 hp	19.3	1.75	183
Tractor "B" — 12 hp	17.7	2.58	218
Tractor "C" — 20 hp	20.0	1.66	229
Panel Truck (hydraulic brakes)	42.0	3.00	44
Truck—145 hp (pneumatic-hydraulic brakes)	40.0	3.30	70

TABLE 2. CLUTCH-PEDAL OPERATING FORCES

Vehicle	Farm job	Measured range, lb	Average values, lb
Tractor "D" — 12 hp	Plowing		44
Tractor "H" — 20 hp	Loading beet tops		70
Tractor "A" — 28 hp	Field transport		77
Tractor "K" — 38 hp	Plowing		88
Tractor "C" — 20 hp (Data taken applying parking brakes on trans. countershaft)	Loading beets		103
Tractor "G" — 12 hp	Road transport	29-88	59
Passenger car — 25 hp	Road driving	35-59	44
Bus — 90 hp	Road driving	88-128	110

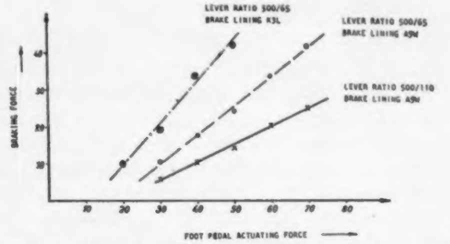


Fig. 7 Improved brake operation resulting from changed leverage and more suitable brake lining

There are many different reasons why tractor brakes are inadequate. Undoubtedly hydraulic or pneumatic brakes are easier to operate, since force transmission from the pedals to the brakes is usually more effective or the operating force is derived from engine power. Pneumatic brakes could well gain importance for farm tractor use, since the air compressor could be used for the operation of a pneumatic power lift as well as inflating tires.

It is frequently found that poor brake operation results from inadequate maintenance. In many instances, there is room for great improvement in the operation of mechanical brakes. On some tractors the dimensions of the brake drums are inadequate. Again, the friction material used in the brakes is of inferior quality, or the leverage system is unfavorable. The action of the brakes of one tractor model was greatly improved by changing the leverage and using a different friction material, as shown in Fig. 7. As a result of these modifications, the pedal pressure necessary for operating the brakes, to afford the necessary deceleration, was reduced 50 percent, from 110 to 55 lb. This reduced the necessary pedal force below the physiologically permissible limit of 77 lb. However, if the brake pedals are improperly located with respect to the physiological requirements of the tractor operator, such improvements are useless. The above considerations are discussed in far greater detail in reference (1).

Clutch. A tractor clutch is operated even more frequently than are the brakes. The force necessary for the operation of the clutch pedal is usually smaller than that required for the brake pedals (Table 2), but since the clutch is used much more frequently, it is just as important that the best location for the clutch pedal be considered. It should be located in a position symmetrical with the brake pedal, with the center axis of the driver serving as the symmetrical axis for both.

Clutch-operating forces were measured on several tractors at several different farm jobs and with different operators. The force applied by the operator against the pedal was measured using a hydraulic measuring device. Tests

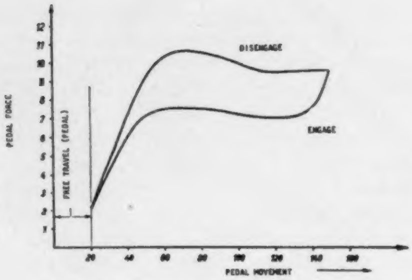


Fig. 8 Pedal-force curve of a Belleville clutch

were made on a farm near Bad Kreuznach, under usual farm conditions. It was found that, where measured under actual farm conditions, the values differ from those determined at the Marburg tractor testing station. At Marburg, the forces measured were those necessary only for disengaging the clutch, while under the field-test conditions described here, the actual forces exerted by the operator were measured. For purposes of comparison, the forces necessary to operate the clutches of a passenger car and a bus were also measured. Table 2 shows some of the data so determined, from which the following results may be drawn:

(a) Table 2 shows that the clutch-operating force is lower than the brake-operating force. Operating forces for smaller and medium-size tractors, as well as passenger cars, are below the physiologically allowable average limit of 77 lb. On tractors with brakes such as parking brakes, acting on a transmission shaft or power line, and on the bus, the required clutch operating forces exceed the physiological permissible limit.

(b) Clutch-operating forces increase with increasing engine power and decreasing engine speed. This is the reason why tractors K and C, having engine speeds of 300 to 700 rpm, require the greatest clutch-operating force. These tractors also have a transmission brake connected with the clutch pedal, which stops the motion of the gears when disengaging the clutch.

(c) The individual data, which were measured on three vehicles only, show that the same driver on the same vehicle, from time to time, applies differing forces to the clutch pedal. This is an amazing fact, particularly since the force required to disengage the clutch remains constant. The reason for this is that when the driver does not feel the point at which the clutch disengages, he either pushes the pedal further than necessary, which means he has to overcome an increasing spring force or just pushes the pedal against the stop. It can, therefore, be understood why the forces, as measured in these tests, are greater than those measured at the Marburg tractor test station.

From the foregoing, it will be seen that it is necessary to indicate in some manner the point at which the clutch is disengaged. The operator then feels when the clutch disengages and does not push the clutch pedal further than is necessary, which, in turn, reduces the strain to which he subjects himself.

One way to accomplish this lies in changing the relationship of the operator's force against the pedal to foot-pedal displacement. The human being reacts unconsciously to changes in resistance. Laboratory tests (1) indicated that a man can detect a 15 percent drop in resistance and acts with an interruption of the foot motion. The clutches used on Opel-Olympis-Rekord and Opel-Kapitän (German-built General Motors) motor cars are equipped with Belleville springs. The clutches on both cars are acknowledged by car drivers to be comfortable. It is important to have a steady decrease in pedal force (Fig. 8) in order to prevent any sudden motion of both the foot and the pedal. The magnitude of the operating force determines the degree of decrease in force for the succeeding ¾ in. of pedal motion, starting at the point of clutch disengagement. An additional means of possibly limiting the pedal motion, and with it all unnecessary operating forces on the part of the driver, lies in the design of the foot rest for the driver's feet (Fig. 9). The upward sloping foot rest limits the pedal motion in such a manner that the heel of the operator's shoe stops against the foot rest, and any further motion is thereby prevented. This form of foot rest has been found to be very comfortable for the driver, even when no pedal is operated. It has proven itself to be highly advantageous.

Accelerator Pedal (Foot Feed). Control of engine speed by means of a foot throttle is easier than by a hand-operated throttle. This is especially the case, since the hands are required for steering, shifting gears, operation of hydraulic controls and engaging the parking brake. The ankle joint is particularly suited to sense a position and maintain close regulation. It was found by analysis of theoretical conditions, and verified by tests (1), that a motion represented by

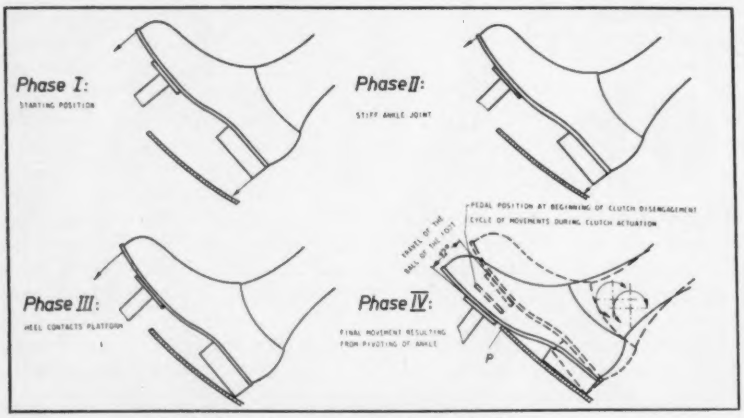


Fig. 9 Four phases of motion during clutch operation

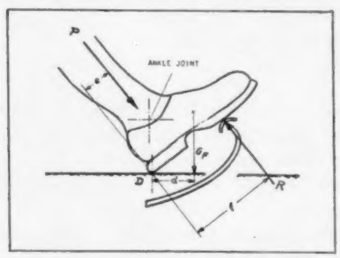


Fig. 10 Forces acting on operator's foot, for calculating return forces for throttle pedal

a 20-deg movement of the ankle affords a sufficient degree of accuracy. This is equivalent to a motion at the toe of the foot of approximately 1⁹⁄₁₆ in. Numerous vehicles require a far greater pedal motion, which in extreme cases, reaches a value of 5½ in. Extreme pedal movement, such as this, requires excessive bending and stretching of the calf and shin muscles, which are both very uncomfortable to the operator. In addition to the magnitude of pedal motion, the force necessary to operate the pedal is of great significance to accurate regulation of engine speed. If the pedal pressure is too high, the energy required to continually operate the pedal is excessive. On the other hand, if the pedal pressure is too low, then the exhausting static muscle drain will be very uncomfortable, since the weight of the foot must be supported by the leg muscle.

Considering the anatomical conditions involved, the minimum pedal reaction may be calculated, considering the pressure applied by the toe of the foot. Taking the angle of the sole of the foot with the axis of the leg at 80 deg, the following formula may be derived from Fig. 10:

$$R=\frac{(G_F d)+(Pe)}{f}$$

where G_f = weight of the foot (3.21 lb)

F = force acting at the ankle joint in the direction of the shin bone, when the shin bone is at an angle of 123 deg with respect to the thigh bone = 17.16 lb (11)

D = 3.62 in

e = 2.53 in

f = 7.87 in

Considering the increased tension of the calf muscles when the foot is so positioned that the toes are lifted free from the foot rest, the spring force of the foot-throttle-control pedal, acting against the foot, should be in the order of 7¾ lb, in order to support the foot sufficiently to relieve unnecessary tension in the tendons. The theoretical value so determined coincides closely with values established in actual tests.

Furthermore, it is important that the foot pedal move in such a direction that the vibrations induced by driving over obstacles will not cause the foot and pedal to shake and vibrate. Otherwise the engine speed will not remain steady. This can be almost completely prevented by allowing the heel of the foot to rest on a steady support. (Fig. 9, phase IV).

Steering Wheel. The steering wheel serves two purposes: (1) to transmit steering forces and (2) to support the body of the operator, to the extent that it cannot be supported by the back rest of the seat due to excessive vibration. The steering wheel should not be too far in front of the driver. It is well known that tall individuals, after having driven a passenger car over a long distance, seated in a rearwardly reclining position, assume a more vertical position as they encounter city traffic and may even adjust the back rest in order that they may sit closer to the steering wheel. With each elbow at the angle of about 90 deg, it is easier to turn the steering wheel through a larger angle or to push harder on the steering wheel rim should it suddenly become necessary. This is particularly true with respect to a tractor operator. Fig. 11 shows the physiologically favorable position of body and arms.

The position of the steering wheel with respect to the operator has a determining influence on the possible steering forces, speed of steering, energy requirement when steering, and the operator's comfort. Laboratory tests show that the highest possible steering forces can be obtained with the steering wheel in a horizontal plane, as is often found in buses and small panel trucks. In spite of this, this steering wheel position is not suited for the operators of tractors and passenger cars, as the hands are not in a physiologically favorable position with respect to the arms, *i.e.*, the hand is always at a sharp angle with respect to the arms.

Steering forces on tractors are generally below the allowable limit of 33 lb. The actual angular movement of the steering wheel and the forces exerted by the operator were measured with oscillograph equipment for different farm jobs and with a test model, for studying how they were influenced by road conditions, amount of steering-wheel movement, type of steering linkage and speed. Time markers were recorded on the same oscillograph trace. Typical samples of the oscillograph are shown in Figs. 12 and 13. Further force and steering angle diagrams may be found in reference (1).

In Fig. 12, for straight-ahead driving only, *a* on the left side shows the steering force to angle curves when plow-

Fig. 11 Physiologically favorable position of upper body and arms when handling tractor steering wheel

Fig. 12 Steering force and hand-wheel movement during field operation

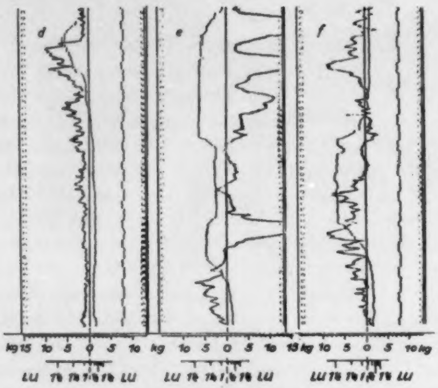


Fig. 13 Steering force and hand-wheel movement during transport and field operation

ing. The steering angle is held nearly constant, as the left front wheel is guided in the plow furrow. The forces are very small, remaining at all times below 4.4 lb. Somewhat higher steering forces are required when cultivating the centers of potato rows. When harrowing on loose, plowed ground, the steering forces show peaks above 11 lb as shown on the right side of Fig. 12. These values prove to be true even on different soils. It was always found that loose soils require greater steering forces.

Diagrams shown in Fig. 13 apply to driving around curves. The strip *d* along the left side shows that the tractor was first driven along a straight road, which later turns to the left. The steering wheel was finally turned to the left for 1¼ revolutions. As a result, the steering forces increased up to 26 lb and return to their original values as the wheel is turned back, since the steering mechanism is inherently self-righting. The initial forces have values of 2¼ to 3¼ lb when turning to the left, since the tractor was driven on the right side of a road which was slightly convex. As a result, the tractor had to be constantly directed towards the middle of the road.

When turning the tractor pulling a harrow at the end of the field, the force applied by the operator at the rim of the steering wheel became so great that the pen of the oscillograph moved beyond the margin of the strip, indicating tangential steering-wheel forces greater than 30 lb. It is interesting to note that the forces go to the right when the steering wheel is turned to the extreme left. The reason for this is that when the front wheels are turned sharply, they tend to slide over the loose soil and introduce reverse forces. Turning the tractor with a plow *(f)*, on the right side of Fig. 13, traveling over a hard dirt road, requires forces of small magnitude to the left.

Further tests showed that especially when working with a front mounted loader, the allowable limits of 33 lb is very frequently exceeded, because of the added weight on the front axle, sharp turning of the front wheels and side slopes. This fact establishes a reason for the great physical strain on the driver when operating with front end loaders. It is, therefore, necessary to pay special attention to steering wheel position and steering gear ratio on tractors which are frequently operated with front-mounted loaders or on side slopes.

Hand-Operated Controls. All hand controls are distinguished by their frequency of operation and the magnitude of operating forces. Field tests revealed that the gear-shift lever and the hydraulic controls are used most frequently. Hand brakes, differential lock, and PTO-engaging lever are not used as frequently. The force necessary to engage hand parking brakes amounted to 22 to 88 lb, and are necessarily regarded as high, as in this case, the same permissible limit of 33 lb should be valid. It has also been found that the hand-operating lifting lever for integral implements frequently required for its operation forces greater than the permissible limit. Hydraulic or pneumatic power lifts save much labor and strain, since in their operation, the tractor engine provides the necessary power and the operator's hand exerts only controlling functions.

Shifting transmission gears does not introduce great strain, so long as the gear-shift lever can be reached without requiring the tractor driver to bend down. This was proven by many tests (1). Likewise, PTO shifting and operating the differential lock—the latter only insofar as it is manually operated—both require only small forces for their operation.

It is important that frequently operated hydraulic controls and gear-shift levers be located close to the steering wheel, in order to minimize and reduce the time for hand movements and prevent excessive movements to the body, as in all such functions energy is consumed. It is recommended that the gear-shift lever be located on the right side, since this is the usual location in automobiles. It is not

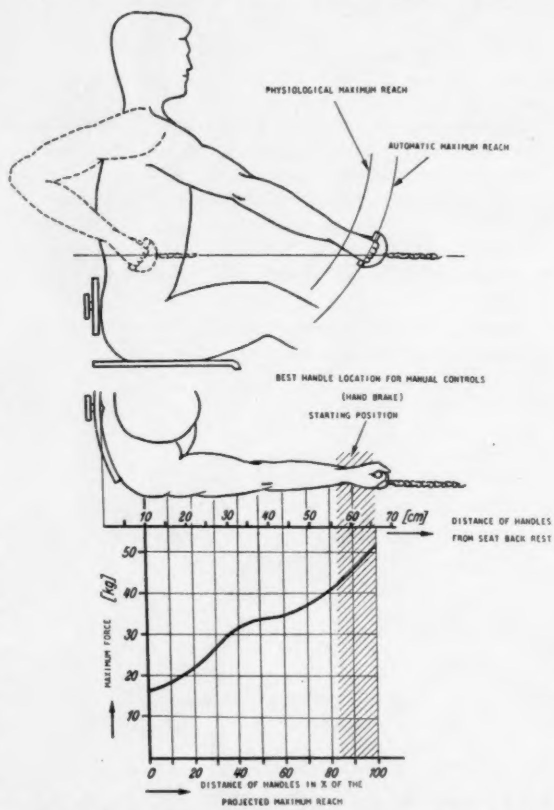


Fig. 14 Relationship of maximum pulling force and locataion of control handle

practical to have one or both gear-shift levers directly below the steering wheel and between the legs of the operator, because in this position, they are hard to reach and interfere with the operator when mounting or dismounting from the tractor. The hydraulic control lever may be either to the right or left of the steering wheel.

It would be highly advantageous to position the tractor gear-shift lever on the steering column below the steering wheel, as is customary in many automobiles.

The location of levers requiring considerable force for their operation, such as the lifting lever for center-mounted cutter bars, parking brake, or the trip lever controlling a front-mounted loader, have to be chosen according to the best position for the operator who is exerting the operating force. Any lever as high as the upper portion of the tractor operator's body is held by him with the elbows more or less bent. In this position, he can exert only small forces (Fig. 14). On the other hand, a seated driver with his arm fully extended can exert rather large forces. This means that such levers should be located close to the perimeter of the space which may be conveniently reached by the operator's hand (Fig. 11). It is clear that it is advantageous to locate these levers at the approximate height of the steering wheel, in order to minimize the movement of the hand, save time and reduce the energy required for their operation.

Adjusting the Controls to Operator's Body Size

There is a difference in human beings, not only as to work output, but in anatomical dimensions. It is self-evident that any seat and control arrangement cannot fit the farmer and his 16-year-old son equally well. Therefore, it is necessary to provide adjustments for both seat and controls to accommodate different body dimensions in order to accommodate individuals of differing size.

It is a wise provision of nature that the dimensions of the limbs of a grown person are always in relation to the size of that person. (These relations are fully discussed in "Heft, 14 Landtechnik 1954, page 388.") Even to this rule, as to all others, there are frequent exceptions. Were one to examine a group of individuals ranging from 62 to 74 in. tall, the average height of tractor drivers will be found to be included within a well-defined range of probability. The average German male adult stands 68 in. tall.

To insure good body positions with respect to all tractor controls, for individuals ranging from 62 to 74 in. in height, the seat and control positions should be adjustable. To provide adjustment for all controls involves many mechanical complications. Furthermore, making such adjustments would frequently result in reduced mechanical advantage—for instance, a shorter foot pedal for a small person would result in higher pedal forces.

Adjusting the seat can generally be done to the advantage of all controls, but there must be a few compromises between hand and foot controls. Therefore, the height of the seat cannot be changed greatly, as for a small person a higher seat would result in worsened foot-pedal relationship. Usually a horizontal seat adjustment is adequate for most persons of differing size. The horizontal adjustment of the seat for persons between 62 and 74 in. in height has to be approximately 8 in. A horizontal adjustment of this amount can be obtained under most usual circumstances without great design effort. Since the length of the human arm does not vary in exact relation to the individual's height and length of leg, it is an advantage to have an adjustable steering wheel. With the driver sitting upright, the steering wheel should be adjustable $\pm 2\frac{1}{2}$ in. in the direction of the steering column (2½ in. upwards and 2½ in. downward, for a total of 5 in.).

Correct Seat Suspension

Some years ago the tractor research institute at Braunschweig-Völkenrode conducted extensive tests regarding proper seating and spring suspensions for farm tractors. The results afforded valuable hints to the effect on the human body when subjected to tractor vibrations.

Such physiological investigations can best be conducted on satisfactory stationary test setups. A vibration table was built and tractor vibrations were simulated. With this setup, different seats with five different test individuals were investigated(1). Comparable tests with tractors driven over field roads were conducted in order to check the results previously obtained. The advantages resulting from a parallel-seat supporting linkage were clearly shown, both in reducing the energy consumed on the part of the operator as well as the resulting nervous strain. It is self-evident that an operator subjected to a purely vertical seat motion will exert less muscular effort in maintaining equilibrium than were he subjected to a nodding motion of a seat which pivots around a single point.

By the same token, a well-damped seat suspension will greatly reduce the muscular effort necessary to intercept jerks and bumps, as compared with a poorly damped suspension. Of even greater importance, the nervous strain was measured and found to be much smaller with a well-damped system than with one undamped. With respect to the energy exerted by the operator and the resulting nervous strain, the widely used leaf-spring suspension was found to be the poorest of the seat suspensions observed.

Environment (Controls and Seating)

As to the final task of this investigation, it was necessary to determine the extent to which human strain could be reduced by improvements in the tractor controls and seat. This knowledge is of importance in order to determine whether a change in seating and controls, made in order to better adapt them to the tractor operator, will pay off. In conducting these tests, the human strains resulting from the operation of two identical tractors with different controls and seating arrangements were measured and compared.

One tractor was tested as delivered from the manufacturer, while the second was modified in accordance with the previous findings. Figs. 15 and 16 show the seats and controls of the two tractors, respectively.

It was necessary to provide a path for easily mounting and dismounting from the tractor, between the engine and the left rear fender, as well as sufficient space for the operator when sitting on the tractor. It was also necessary to widen the space in front of the seat, which resulted in modifications of the fuel tank, dashboard, and battery. In this manner, the unduly steep direction of the forces necessary to operate the pedals was changed so that the resulting flatter direction of the force application was more comfortable when operating the clutch and brake pedals. By improving the brake operating leverage, providing better brake linings and employing a different retracting spring,

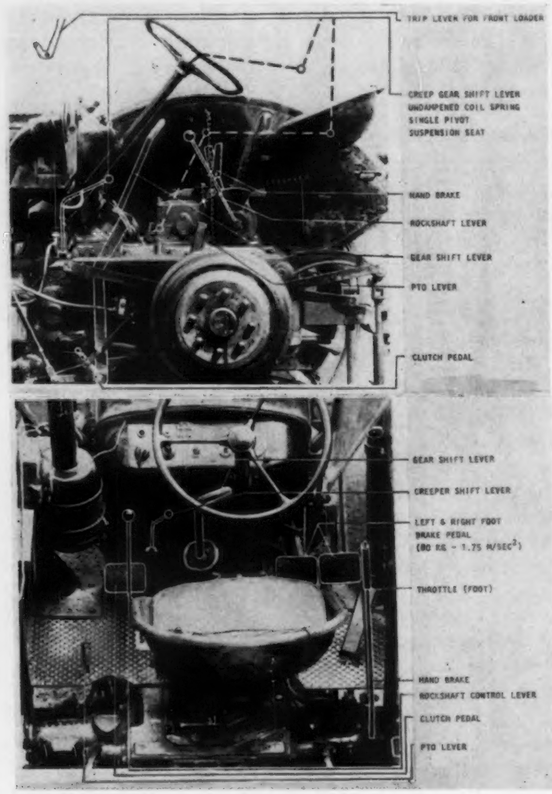


Fig. 15 Controls and seat arrangement of a tractor as delivered

operating forces of the foot pedals were decreased below the physiologically allowable limit. In regard to the foot-throttle control, optimal values of the 1.6 in. of motion and 7.7 lb operating force were realized. A concave footrest was made of expanded metal, which permitted the operator's feet to rest in any desired position and thus avoided premature fatigue.

With regard to hand controls, the gearshift lever was moved from a central position, between the legs of the operator, to the left side. For design reasons, it was possible to move the gearshift lever only to the left side; otherwise a location to the right of the operator would have permitted easier operating and provided better access to the seat for mounting and dismounting. It was not possible to move the hydraulic-control lever, from a very unfavorable location on the left side and below the seat, into close proximity to the steering wheel, since the hydraulic system would then have been completely changed around. On the other hand, the shift lever for the creeper gear was extended and brought up within reach of the operator, so as to avoid his bending down. The manual brake lever was also extended and the handle located within easy reach of the operator. After this change, it was readily accessible with the arm nearly stretched out fully, which made it easier than before for the operator to exert the necessary force.

The trip lever for the front-end loader, which previously had been mounted on the loader frame, and moved up and down accordingly, was fastened onto the fender within convenient reach of the operator. Although this arrangement made it necessary to guide the trip rope through the pivot point of the loader frame, the resulting operation was much easier.

The position of the steering wheel was changed in such a manner that the operator could grip the rim of the wheel when sitting in an upright position, with his elbows at an angle of about 90 deg. The angle between the steering column and the horizontal was determined to be 55 deg. A seat suspension with parallel linkages and a hydraulically damped spring was provided, which had been previously found to have superior suspension characteristics when tested on the vibrating table. The seat and cushions were adjusted to the operator, with the back rest extended vertically to a height of approximately 9½ in. This resulted in better reaction to the foot-pedal forces.

Since it was not possible to readily and completely change the mass produced tractor, many compromises were necessarily made. But this simple example of modifying the tractor showed that insignificant changes of controls could frequently bring great improvements. Surely the design of a new tractor would afford far greater opportunities for adapting the controls to the human body.

Both tractors — the original and the modified models — were tested and compared under identical conditions, at various farm jobs and employing the same operating personnel. The strain on the operator was measured by both the respiration and the heart-beat frequency methods. In

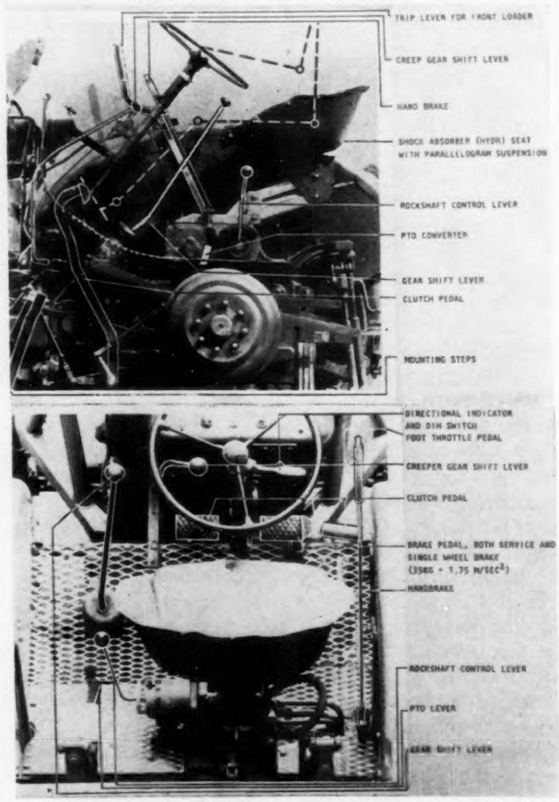


Fig. 16 Controls and seat arrangement of the same tractor as in Fig. 15 after modification

order to insure correct data, the tests were repeated four times. Table 3 shows the results of these tests.

From these results, it may be seen that the improved tractor decreased the energy consumption required of the operator by amounts ranging from 13 to 29 percent! Such a reduction in human effort is indeed significant. The reduction, as determined by the heartbeat frequency method, amounted to 40 to 45 percent. It is higher, since it takes into account the highly fatiguing static muscle effort, which was greatly reduced on the improved tractor. Not all characteristic factors of human strain were measured. There were, for instance, no measurements taken of nervous strain. In addition to the subjective feeling of the tractor operators that the work was easier, the measured data show very distinctly that a suitable arrangement of controls and seat can significantly reduce the strain on the tractor operator.

TABLE 3. REDUCTION IN HUMAN ENERGY EXPENDITURE RESULTING FROM IMPROVED CONTROLS AND SEATING

	Driving over field road	Plowing	Loading manure with front-mounted loader
1. Energy expended (Kcal/min)			
Unmodified tractor	1.65	2.31	4.32
Improved tractor	1.25	1.65	3.72
Reduction:			
net	0.40	0.66	0.60
percent	24.2	28.5	13.9
2. Heart beat frequency (Increase over normal pulse per minute)			
Unmodified tractor	22.8	23.9	36.2
Improved tractor	13.4	14.7	20.1
Reduction:			
net	9.4	9.2	16.1
percent	41.2	38.6	44.5

Arrangement of Controls in Motor Cars and Trucks

As was the case with tractors tested, the arrangements of controls and seats in several motor cars and trucks were evaluated and compared with optimal values. As examples, the foot-throttle control (accelerator) and the steering-wheel position of one mass-produced car and a widely used heavy truck (both 1956 models) will be discussed. Figs. 17 and 18 show in heavy lines the original positions of the foot accelerator, steering wheel, seat and driver. Dotted lines show the optimal positions (see also Fig. 11), with the driver sitting in an upright position, as is necessary for tractor operators on account of severe vibration. It has been found advantageous to incline rearwardly the back rest of fast-moving and well-sprung passenger cars. When this is done, all hand controls must necessarily be relocated further to the rear. Fig. 17 shows that the height of the seat above the floorboard is much lower than the optimal height. This does not influence the operation of foot pedals. However, it does preclude the possibility of resting the foot which does not operate the accelerator in a comfortable position as far back as the forward edge of the seat. It could be done, but only with the knee in a higher position, which decreases the available space between the thigh and steering wheel. The muscles of the calf and the shin are then in a fatiguing position, since the ankle is under tension and the toes of the foot pushed upward. The concave, upward sloping footrest of the optimal arrangement, as shown in dotted lines, provides a comfortable resting position for the foot in each fore-and-aft location, since the thigh is always in the same position and the lower part of the leg is moved from one position to another by simply pivoting around the knee.

As a result of the low seat height, the thigh cannot rest completely on the seat, the accelerator pedal is too high and is therefore operated by the toe and not by the sole of the foot, with the heel of the foot resting on the floor board. Furthermore, the foot is under continual stress, since it is no longer in its physiological zero tension position (Fig. 11). Such an arrangement leads to premature fatigue, especially when the reaction of the accelerator-pedal spring is not correctly adjusted. *(Continued on page 525)*

Fig. 17 Body position of passenger-car driver with accelerator and steering wheel in original and modified positions (dotted lines)

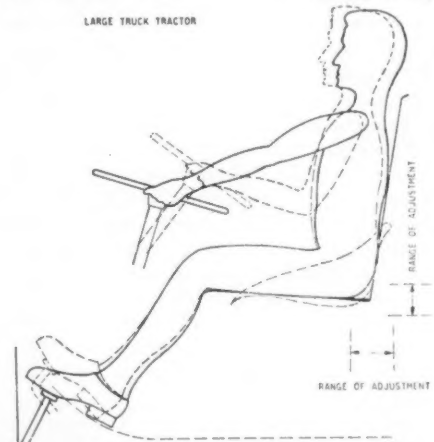


Fig. 18 Body position of truck driver with accelerator and steering wheel in original and modified positions (dotted lines)

Engineering Psychology in Farm Equipment Design

Ernest J. McCormick

Potential applications of psychological research, or human engineering, to mechanical design problems

FIRST of all, let me explain why a psychologist is taking part in a meeting of agricultural engineers. There are, of course, various branches of psychology, including certain branches that are of a distinctly applied nature. These applied branches include experimental psychologists and industrial psychologists, and, in recent years, some who are referred to by the term "engineering psychologists." The engineering psychologists are those who have become associated with what is now being called *human engineering.* While I do not like the term "human engineering" in some respects, it seems one that is destined to stick with us, and I suppose we might as well get used to using it.

Human engineering refers to the design of work equipment, tools, instruments, and working environments that contribute to optimum human use. Such design problems obviously are the responsibilities of engineers. In this endeavor, however, there are various other professions which contribute information for the development of human-engineering principles. These professions include physiologists, anthropologists, physicians, and psychologists. The interests of these professions in human engineering is one of developing principles which can then be used by engineers in designing equipment, tools, and work environments. As I view this development, it is essentially one of several professions operating in something of a complementary manner towards certain common objectives. I see nothing in this type of cooperative effort that is at all suggestive of anyone stepping on anyone else's toes, or taking over anyone else's prerogatives.

At this session, we are interested in the contributions of psychology to farm equipment design. In discussing this subject with you, however, I want to make it clear to begin with that I will not discuss the *present, immediate* applications of psychology to farm equipment design, but rather will suggest some of the *possible* applications. I am going to follow this tack, since thus far engineering psychologists have not contributed much that is specifically applicable to some of your problems. It seems to me, however, that there are many potential applications, and it is some of these that I would like to discuss. Having a somewhat practical point of view on some of these matters, I would prefer to do this by example rather than by crystal-ball gazing. I would like to illustrate some of the kinds of research that have been carried out by psychologists which have at least some relationship to the problems of farm equipment design. These examples come from a variety of topics, such as truck-cab design and some of the military research that is being done (especially in connection with aircraft), and other areas.

Paper presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1957, on a special program on the theme, "Ergonomics in Farm Equipment Operation," arranged by the Power and Machinery Division.

The author — ERNEST J. MCCORMICK — is professor of psychology, Occupational Research Center, Purdue University.

Before discussing these examples, however, I will add one additional general comment regarding designing for human use. That which we now call human engineering is, in one sense, as ancient as mankind. Ever since the first cave man started to use some kind of crude weapon or tool, man has been striving to design things he uses in order to make them more effective, and to make his work easier. The primary basis for judging whether a particular design of club was better for beating one's wife than another kind of club was experience. For centuries, then, experience has served as the guide by which different kinds of equipment and tools have been judged as being satisfactory or unsatisfactory. It might be asked, then, why the current hullabaloo about human engineering? I think the answer to this question lies essentially in the fact that with increasing technological developments, man's experiences in many situations are not sufficiently adequate to serve as a backdrop against which equipment designs can be judged. It is here that systematic research can come into play, and it seems to me that such research is the "something new that has been added" to man's efforts to design things which better serve his purposes. Let me cite an example of a "post-mortem" nature. There have been many airplane accidents, both military and civilian, that have been positively attributed to errors in reading altitude with the altimeter instrument that has been in common usage. Subsequently research has demonstrated that it would be hard to design an altimeter that was *more* difficult to read and that resulted in *more* altitude-reading errors, than the one that has been in use. How much better it would have been if the research that points the way to improved design would have been carried out *before* the one in use had become so frozen in design.

A design problem that has some parallel to that of agricultural tractors is the design of truck cabs and their equipment. Dr. Ross McFarland of the Harvard School of Public Health has conducted numerous studies relating to truckcab design, including some surveys of the adequacies and inadequacies of truck cabs of existing designs. Among the limitations of some designs are the following(3)*: In some trucks it was found that the distance between the steering wheel and brake pedal was so short that many drivers could not get their knee under the steering wheel when applying the brake. This would make it necessary for them to appy the brake with the leg at an angle rather than straight ahead, in which position the braking force would be less than with a direct downward thrust. In the case of one truck cab this dimension was such that 70 percent of the drivers would have this difficulty. In certain other instances it was found that the position of the gearshift lever interfered with the shifting of the leg from the accelerator to the brake. In the case of some individuals it

*Numbers in parentheses refer to the appended references.

was even necessary to shift to another gear in order to be able to transfer the foot to the brake pedal. A delay of even a fraction of a second in being able to apply the brake may, of course, be disastrous. As an example of another type, it was found in certain trucks that the hand brake was in such a position that when the operator was using it, he would have to move out of his normal driving position (4).

In connection with truck-cab design, a recent study was carried out at Purdue that illustrates how a systematic analysis of a particular design problem can contribute to design improvement for human use(2). In this study an experimental mock-up of a truck cab was used. There were nine possible adjustments that could be made to the truck cab arrangement, as follows: vertical seat and adjustment, horizontal seat adjustment, angle of the seat bottom, angle of the seat back, length of the seat bottom, angle of the toe pan, vertical adjustment of the steering post pivot, angle of the steering post, and length of the steering post. In the experiment, each subject adjusted all of these features to create that combination of arrangements that he considered to be most satisfactory to him. He could make varying adjustments during the time he was performing on a simulated "driving" task. The simulated driving task consisted of operating the steering wheel to control the movement of a pointer on a simulated road on a display across the room. At the end of his driving task a record was made of the adjustments that were most satisfactory to him. This was repeated three different times, and the average of his various settings was taken as the design which was most satisfactory for him. At later dates he performed on the driving task with the truck cab set at each of three combinations, namely, combinations of two fairly common cabs, and, the third, the average of his own adjustments. He was not told at this time which was the combination which he himself had previously chosen. For these three driving tasks a record was made of the "time off road," in seconds, with the following results:

DRIVING PERFORMANCE IN SUBJECT'S CAB VS. STANDARD CABS

Cab	Time off road (Seconds)
Subject's cab	70.5
Cab A	83.8
Cab B	115.4

While this study was admittedly carried out in an experimental setting, it at least suggests the possibility that performance in a driving task may be related to the extent to which the features of the cab are appropriate for the individual in question. In connection with this particular study it might be added that it was found that five of the variables were significantly related to driving performance, these being vertical seat height, horizontal seat position, length of seat bottom, height of post pivot, and length of steering post. For each of these a range of possible settings was suggested on the basis of the results of the experiment.

Another example is related to a somewhat different aspect of equipment design. Most pieces of machinery or equipment incorporate instruments or other locations to which the operator must give his visual attention. In addition, there typically are certain kinds of control devices such as wheels, levers, buttons, and so forth, that need to be activated on the basis of the information which the operator has received from his equipment or his environment. In the transfer of visual attention from one location to another, it is sometimes critical for the operator to make as rapid a transfer as possible of his attention. In the transfer of the hand or foot from one control device to another it may also be critical that the transfer be as rapid as possible. A systematic analysis of operator functions can provide information which will result in the arrangement of instruments or other areas of visual attention to facilitate rapid transfer of visual attention, or the arrangement of control devices to contribute to efficiency in the operation of these. This can be done by systematic analysis of operator functions such as was carried out with aircraft instruments in one study by the U.S. Air Force(1). By the use of an eye camera a film record was made of the movements of the eyes of pilots. On the basis of this film, it was possible to determine systematically the extent to which transfer of visual attention was made from one instrument to another. This information made it possible to determine the frequency with which visual attention was transferred from each instrument to each of the others. With information of this type the instruments could be rearranged in order that the pilot would, when shifting attention from one instrument to another, do so in as short a period of time as possible. The same type of analysis can also be made with various types of control devices that are used on pieces of equipment, resulting in the arrangement of those control devices to facilitate their use.

In connection with the transfer of visual attention, there have been at least two exploratory studies related to the visual functions of tractor operators. One of these, carried out by The National Institute of Agricultural Engineering in England(6), dealt with the influence of the operator's position on steering performance in row-crop hoeing. The other one, a pilot study we have recently completed, was essentially a methodological study. Its purpose was that of developing a method for the analysis of moving-picture films to determine the locations to which the operator gave his visual attention. This was done by analyzing a combination of eye and head movements. While studies such as these have not yet produced very much in the way of factual information, they are at least suggestive of the types of analyses that can be made of tractor operation. Knowing what pattern of visual attention is required in various tractor operations, it might then be more feasible to position the operator on the tractor in such a location that his visual attention can be given most effectively.

Another aspect of engineering design in the design of tractors and other types of farm equipment is that relating to the control devices that are used. In the design of control levers, for example, the design engineer is presented with the alternatives of varying the *distance* of movement required to accomplish a particular amount of change in the machine, or in varying the *amount of force* which the operator needs to overcome in operation of the lever. Looking at it from the point of view of the operator, if he is to control the *degree* of change in operating the lever, he has to receive information cues that help him in judging how much change in the lever is enough. He can receive such cues from the *distance* he moves the device, or by the *physical resistance* of the device, or by a combination of these two. One might then ask which of these sources of information provides the most *reliable* cues for him to use in controlling his actions. A study carried out by the Special Devices Center of the Navy dealt with this (5). In general terms, it was found that the distance of movement is the

(Continued on page 527)

Steering-Force Requirements of Wheel Tractors

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Results of Research Studies of Human Forces Called for in the Steering of Wheel-Type Farm Tractors

THIS paper presents the results of studies of human forces required to steer wheel-type farm tractors, the primary object of which was to assess the working conditions of farm tractor drivers with particular emphasis on drivers with impaired hearts. (Obviously information about the working conditions of cardiac impaired drivers would also be applicable to normal drivers.)

A continuing increased demand for improving the steering system of farm tractors is in prospect because of *(a)* increased size of tractors, *(b)* increased speeds, *(c)* increased size and weight of implements, and *(d)* increased demand for accurate steering (e.g., cultivation). This paper deals with the effect of external forces (e.g., loader) upon the steering system, and with the effect of certain devices to improve the steering.

Paper presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1957, on a special program on the theme, "Ergonomics in Farm Equipment Operations," arranged by the Power and Machinery Division. Authorized for publication as Journal Paper No. 1212 of the Purdue University Agricultural Experiment Station, Project 712, co-sponsored by Purdue University, Indiana Heart Foundation, American Heart Assn., Indiana State Board of Health, and the National Institutes of Health.

The authors—J. B. LILJEDAHL, R. GLUCK, and M. E. SCHROEDER—are, respectively, associate professor of agricultural engineering, Purdue University; engineer, U. S. Rubber Co., and assistant professor of agricultural engineering, Pennsylvania State University. (Both junior authors were formerly graduate research assistants at Purdue University.)

Acknowledgment: The authors gratefully acknowledge the assistance of the John Deere Waterloo Tractor Works and the Indianapolis (Ind.) branch of the J. I. Case Co. in connection with the research study reported in this paper.

Chandler(3)* in 1925 made steering-force measurements which resulted in improved mechanical steering systems for automobiles. Continued improvement of steering gears in the past 25 years has increased the steering-gear efficiency from about 20 percent to around 80 to 85 percent. The increased efficiency has resulted in reduced steering forces, but has also increased the transmission of road shock forces.

In 1955 Dupuis *et al*(2) published an extensive report in Germany on steering forces of manually steered tractors. Some of their conclusions were as follows: *(a)* Speed affected steering frequency, *(b)* mowing required over 1200 steering corrections per hour, *(c)* manure loading required the largest steering forces, *(d)* forces exceeding 22 lb were experienced over 20 percent of the time when driving in a plowed field, *(e)* a side-mounted mower caused many more corrective motions than one trailing the tractor. Dupuis measured steering-wheel motion as well as steering forces and time.

Procedure of Purdue Studies

It was decided to measure the steering forces under what seemed to be the most severe conditions, as follows:

(1) Large row-crop tractor with 4-row cultivator
(2) Large row-crop tractor with manure loader
(3) Large row-crop tractor crossing 5-in. bumps.

SR-4 strain gages were mounted on the steering shaft so as to measure the torque. This method of measuring torque has been described by Dobie(1) and Gluck(4). No attempt was made to measure the angular displacement of the wheel, nor to compare one tractor with another.

*Numbers in parentheses refer to the appended references.

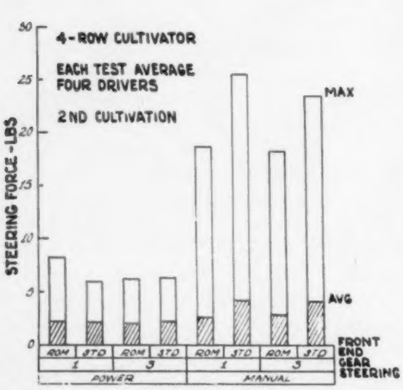

Fig. 1 Steering forces for John Deere 70 tractor and cultivator

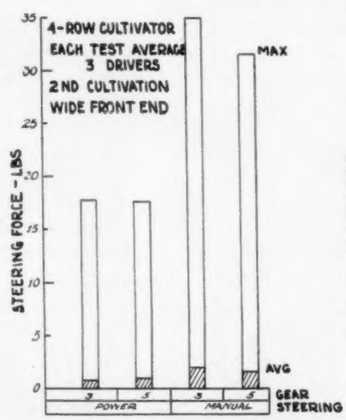

Fig. 2 Steering forces for Case 400 tractor and cultivator

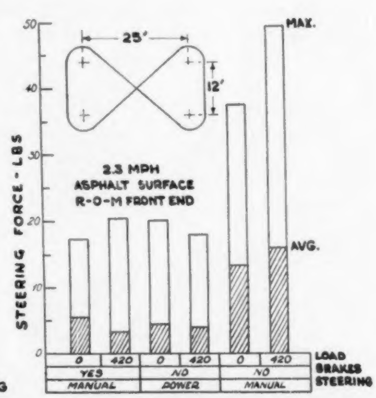

Fig. 3 Steering forces for John Deere 70 tractor and loader

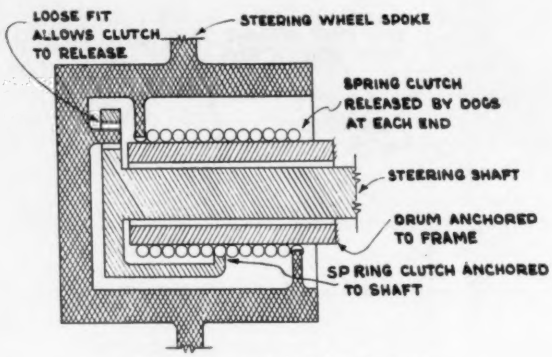

Fig. 4 Schema of Kosch steering aid

Two John Deere 70 tricycle-type tractors were used, one with power steering and the other with manual steering. Both tractors could be used with the roll-o-matic front end or with the conventional rigid front end.

The Case 400 tractor was equipped with a wide front end and could be converted from power steering to manual steering.

The Farmall 400 was of the tricycle type and was manually steered. All tests were performed by at least two drivers and some by three and four.

Cultivation Tests

The John Deere 70 was used on the first and second cultivation and at two speeds. The Case was used only on the second cultivation and also at two speeds. Both the maximum and average forces were determined; however, the steering forces while turning at the end of the row were not considered. Four drivers were used on the John Deere and three on the Case. The results are shown in Figs. 1 and 2.

Comparison of the steering forces required by the John Deere and the Case tractors is not possible because of differences in the conditions of the tests. The Case was used in a different field and was equipped with wide front wheels. In addition, the Case cultivator weighed approximately 400 lbs more than the John Deere cultivator.

The roll-o-matic front end on the John Deere caused a 25 percent reduction in average and maximum forces during the second cultivation when the ground was rough, but had no effect during the first cultivation. During the first cultivation power steering on the John Deere reduced average steering forces approximately 41 percent and the maximum forces were reduced by 78 percent. Speed in the range studied had no appreciable effect on steering forces while cultivating with either the Case or the John Deere. Power steering reduced average and maximum steering forces by approximately 50 percent on the Case tractor. It appears that the drivers attempted to steer too fast with the Case causing temporary high steering forces before the power steering became effective.

Loader Tests

Since a loader imposes a very heavy load on the front end, it is natural to assume that the static steering forces will be increased considerably. When turning, centrifugal force causes an additional steering force because of the caster of the front wheels. The tractor was driven in a figure of eight around markers placed in a rectangle 12 by 25 ft. All

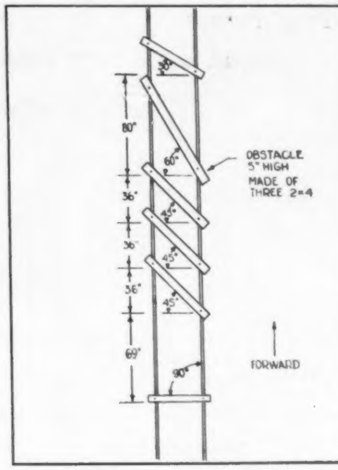

Fig. 5 Obstacle course for testing steering aid

tests were performed only with the John Deere 70. The results of the figure-of-eight tests are shown in Fig. 3.

It is obvious that steering forces when using manual steering on the John Deere 70 equipped with a loader were excessively high. Power steering reduced the average force by 75 percent and the maximum by 67 percent when carrying a load. The added load to the fork made no appreciable difference for power steering, but did increase the steering forces for manual steering. However, use of differential brakes under the same conditions had almost the same effect as power steering. It is important to note that under normal operating conditions, including starting and stopping, it would not be possible to take complete advantage of the differential brakes.

The preload on the John Deere power steering was approximately equivalent to 5 lb of force on the rim of the steering wheel. This is the steering force necessary to open the spool valve and begin the power assistance. One might wonder why on both the cultivator and loader tests the maximum steering forces exceeded the preload setting by such a large value. The only logical explanation is that the drivers attempted to steer too rapidly, and therefore were temporarily turning the wheel at a rate faster than the power assistance could follow. (It can be assumed that drivers accustomed to a particular power-steering system would adjust their reflexes so as not to overtake the power assistance, but no tests were made to check this.)

In other tests, with the John Deere tractor moving dirt from one pile to another with a loader, it was observed that power steering reduced the cycle time by 10 percent. Steering forces were not recorded in the dirt-moving tests.

Bump Tests

One of the complaints made of tractors with manual steering is that shocks are transmitted to the hands. No statistics are available, but it has been reported that farmers have received broken fingers and thumbs because of the tractor striking a rock or severe bump with a front wheel. Power steering will, of course, remove most of the road shock.

Road shocks can also be reduced by holding the steering shaft with a spring clutch as in the Kosch. The design of

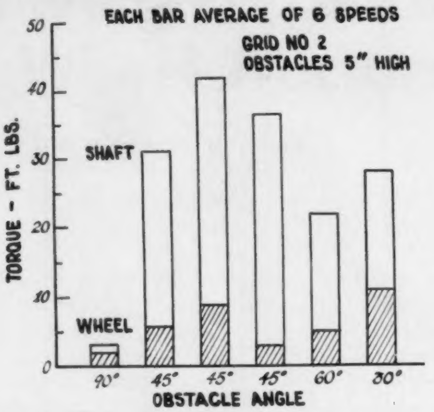

Fig. 6 Torque transmitted to steering wheel when using steering aid on Farmall 400

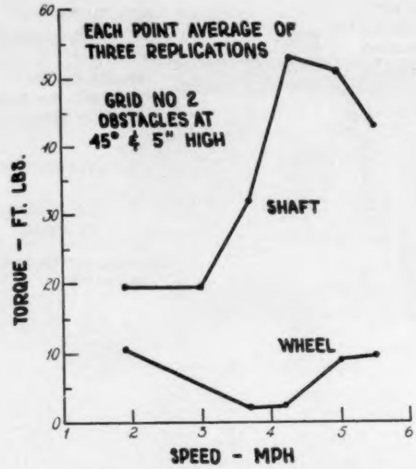

Fig. 7 Torque transmitted to steering wheel when using steering aid on Farmall 400

spring clutches has been described by Kaplan(5). A schematic diagram of the Kosch steering aid is shown in Fig. 4. Actually the device in this case is used as a brake which can only be released by moving the steering wheel in either direction. If the steering wheel is not moved, all of the torque on the steering shaft is absorbed by the tractor frame. If the brake is partly released, some of the road shock will be transmitted to the hands.

The effectiveness of the steering aid was tested by driving a Farmall 400 tractor over an obstacle course. Torque on the steering wheel and the steering shaft was measured simultaneously by SR-4 strain gages in conjunction with Brush instruments. The obstacle course is shown schematically in Fig. 5. The results of the bump tests are indicated in Fig. 6.

The 45-deg obstacle caused the worst shock to the steering shaft, 82 percent of which was removed by the steering aid. It should be emphasized that the steering-wheel forces (Fig. 6) *cannot be duplicated,* because the torque transmitted to the steering wheel depends entirely on how much the brake was released when the wheels struck the bump. If the wheel was being turned, then the brake was released and all of the shock torque was transmitted to the hands. If the wheel was not being turned, then most of the shock torque was absorbed in the tractor frame.

Fig. 7 shows the effect of speed on the shock transmitted to the steering shaft and wheel. As would be expected, the torque in the shaft increases with speed, but the wheel torque is relatively unaffected.

Conclusions

1 The roll-o-matic front end on the John Deere 70 reduces average and maximum manual steering forces 25 percent when cultivating corn the second time.

2 On the John Deere 70, power steering reduced average steering forces 41 percent and maximum steering forces 78 percent when cultivating corn.

3 Speed had no measurable effect on either the John Deere 70 or Case 400 while cultivating corn.

4 Power steering reduced average and maximum forces by 50 percent on the Case tractor while cultivating corn.

5 Maximum forces were greater than the preload setting on both the Case and John Deere tractors. This is probably because the drivers were, for a short time, steering at a rate greater than the power steering could follow.

6 When the John Deere 70 was equipped with a front-end loader and driven in a figure of eight, power steering reduced the average steering force by 75 percent and the maximum by 67 percent. Under exactly the same conditions, use of the differential brakes had almost the same effect in reducing steering forces as power steering.

7 The weight on the fork of the loader on the John Deere 70 tractor had no effect on the steering forces when using power steering.

8 When loading manure with the John Deere 70 tractor, power steering reduced the loading time by 10 percent.

APPENDIX

TABLE 1. SPECIFICATIONS OF TRACTORS AND EQUIPMENT

	John Deere 70		Case 400		IH 400
	Manual	Power	Manual	Power	Manual
Steering ratio	16.5:1	14:1	16:1	16:1	16.35:1
Steering wheel diam., in.	20	17	18	18	17⅞ (steering aid)
Preload of power steering		5 lbs on OD of wheel		2 lb plus proportional on OD of wheel	
Weight cultivator, lb	1600		1992		
Front tire size	6:00 - 16		6:00 - 16		6:00 - 16
Front tire pressure, psi	44		44		28
Tractor type	Tricycle		Wide front end		Tricycle

9 When a Farmall 400 tractor was equipped with a shock-absorbing steering aid the shock from driving over angled 5 in. bumps was reduced by 100 percent, *if* the driver was not turning the wheel. If the driver was turning the wheel, all of the shock could be transmitted to the hands. The most severe shocks were caused by bumps set at a 45-deg angle.

10 When 25 ft-lb of torque was applied manually to the steering wheel, approximately 25 percent was absorbed by the steering aid.

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. . . Tractor Operation

(Continued from page 519)

The steering wheel was located well to the rear, due to the sloping position of the back rest, but even this was not quite far enough. As a result, the angle of the elbows (which should be approximately 90 deg) was too great for fast reaction, with low small-energy consumption, when the steering-wheel exertion is high.

The large truck had a very poor steering-wheel location. It was much too low and too far ahead of the operator. When leaning against the back rest, it was necessary for the operator to steer with his arms completely stretched out. This is an impossible situation. Only a driver with unusually long arms could handle such a truck comfortably; a smaller person could not lean back against the back rest. The range of adjustment of the seat is intended for larger or smaller persons, *i.e.,* for persons who differ from the normal-sized human being.

The horizontal floor board position of this truck was much too low, with respect to the seat. The leg which was not operating the pedal can swing freely without touching the floorboard. This results in cutting off the arteries located between the thigh bone, and the leg will go to sleep. Because the heel of the foot which operates the accelerator cannot rest on the floor board, it is not possible to accurately control engine speed. As a result, the leg will very soon be subjected to fatigue resulting from static muscular effort.

A measure of built-in adjustability of this seat could improve the arrangement somewhat for normal-sized persons, but this would be quite unsatisfactory for others, as individuals smaller than the normal or average size will be required to sit very uncomfortably. Experience shows that quite often seat pads are used in order to improve a poor seat arrangement. However, this is rarely successful.

The few examples discussed in this paper are intended to show that the designs of modern tractors, as well as passenger cars and trucks, may be modified to reduce the strain and fatigue of the driver. This is especially true when physiological factors necessary to the most favorable seat and control arrangements are considered and applied.

Conclusions

In this paper are the most important points investigated and the resulting findings of a research project dealing with the reduction in tractor operator effort and stress, resulting from better design of seat and controls. As a first step, the work load imposed upon the operator of a tractor was measured and compared with other occupations. Next investigated were the causes for the high degree of stress which were observed and the means taken to effect improvements. These investigations involved the following aspects, namely, the respiration method of evaluating human effort, the frequency of heart beat methods used in evaluating the effort of tractor operators, measurement of the necessary operating forces, best control positions and most favorable seating arrangements and suspension types.

Tractor parts coming in contact with the operator were modified and improved in accordance with the latest findings. Reductions in the operator's effort as high as 45 percent resulted. In addition, the optimal seat and control arrangements were compared with those of modern passenger cars and trucks. This showed that substantial reductions in operator effort can be effected in all types of motor vehicles, when the seat and controls are better engineered to the operator.

It, therefore, follows that the conclusions regarding the basic relationships of operator, seating and controls are of importance to all automotive designers.

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Psychological Aspects of Farm Work Efficiency

Melvin A. Schmitz

Progress toward integrating the farm worker and his machine for maximum efficiency

THE study of the effect of stimuli impinging on man by way of sensations and perceptions and man's response to these stimuli, through motor reaction, has long been the concern of experimental psychology. However, research dealing with man and a group of stimuli and responses found in a specific man-machine environment system has gained impetus only in the very recent past. It was not until World War II that a small group of psychologists, at the request of the military, began a close study of the relationship between man and the machine he operated. And it was not until then that we began to understand clearly that man had certain capabilities that could be used to advantage, and also certain limitations in what could be expected of him in specific man-machine situations. Most of you are perhaps familiar with the content and results of these early studies—the arrangement of controls; the redesign of knobs, dials, levers; the elimination of blind spots in the visual field; criteria for optimum friction applied to controls and forces necessary to move them efficiently; the design of seats with adequate adjustments for various work situations, and so on.

In these early stages, psychologists and design engineers worked together to integrate the man and his machine in such a way that maximum efficiency could be obtained. Over the past 10 years, the field of study has grown from interests in specific components to one of systems design and analysis. The question asked has changed from "How can we change this component to aid accomplishment of a mission?" to "What is the mission of the system (man and machine) and how can it be accomplished most efficiently?" Instead of a psychologist and a design engineer working together, we now have teams of medical doctors, psychologists, physiologists, economists, physicists, mathematicians, and engineers, all working on the same systems problem. We no longer necessarily design a machine and rely on man's large fund of adaptability to make it work, but instead the machine is designed in such a way that man and machine can do their job with a maximum of safety in a minimum amount of time, with great precision, without large expenditures on energy, and in agreeable surroundings.

Now what does all this have to do with farm-work efficiency? As a psychologist interested in research dealing with man-machine relationships in land vehicles, my interest is in variables that affect the psychomotor performance of the farmer in the operator-tractor system. I am interested in the factors of health and safety of the farmer, in his performance and personal well-being, and how these factors affect his work efficiency.

Paper presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1957, on a special farm work efficiency program.

The author — MELVIN A. SCHMITZ — is chief engineering psychologist, Bostrom Research Laboratories, Milwaukee, Wis.

Designing a tractor with sufficient horsepower and drawbar pull capable of doing twice the work that present-day tractors can accomplish doesn't necessarily mean that the machine will be used at its maximum efficiency. If the man who controls the tractor is not taken into account and if the design does not include arrangements whereby he can control the machine adequately at maximum output, the new design hasn't accomplished its purpose. The man in this situation may be the limiting factor, not because he couldn't possibly accomplish the job, but because the design may not have taken the fullest advantage of his capabilities, allowing him to perform in such a way that the man-machine system can operate at or near the limit of peak efficiency.

Some of the variables that limit man to less than optimum performance have been isolated by past research. Many need further study. This paper is intended to summarize briefly much of what is known to date, that could be applied to the tractor-farmer system, and then to discuss in more detail one of the variables that is now being studied in our laboratory.

Past research has shown that several environmental variables can affect man's performance generally. Significant impairment has been shown to take place when effective temperatures reach 85 F. The factors that have been reported as impaired include: *(a)* visual attention, *(b)* hand coordination, *(c)* motor coordination, and *(d)* forces that can be exerted. Also, at temperatures of −20F or below, finger dexterity, reaction time to a light, and hand-grip pressure are significantly impaired.

Reports have also shown that a single, prolonged exposure to bright sunlight affects subsequent dark adaptation for several hours by slowing the rate at which sensitivity increases, and that glare can result in relative blindness if the glare source is brighter than its surroundings.

Continuous noise with intensity of 115 decibels or over (although it does not appear to affect performance) for one-half hour duration, may affect auditory sensitivity for as much as four hours and has been shown in some studies to increase energy expenditure and muscular tension. As far as the machine itself is concerned, many studies have shown that performance can be improved by design changes in the following: *(a)* placement of controls and displays, *(b)* shape of controls and dials, *(c)* coding of controls, *(d)* arrangement of work space, *(e)* seat design, and *(f)* friction and force requirements for controls.

The last variable to be discussed in this paper is vibration and its effect on work efficiency.

Past research over a wide range of frequencies and intensities of vibration has shown that man's physiological and psychomotor performance is generally affected by vibration. That the frequency and amplitude studies in the past have not included vibrations typically encountered by drivers of

rubber-tired tractors and trucks is unfortunate, and has made it necessary for our laboratory to embark on an intensive study of the effect of low-frequency, relatively high-amplitude vibrations on man's performance. However, the general conclusions of past reports are of interest and in summary are these: *(a)* visual acuity is impaired, *(b)* manual steadiness is affected, *(c)* the balancing senses are irritated, *(d)* pulse rate and blood pressure showed variations with larger amplitude, *(e)* metabolic rate was increased, and *(f)* physical weariness and depression were reported by subjects.

Our present research is concentrated in the range of frequencies from 1 to 7 cycles per second with amplitudes ranging from 3⁄16 to 1 1⁄8 inches. This range has been chosen on the basis of distributions reported by Simons and Radke as being typical vibrations measured on rubber-tired tractors and trucks.

When man sits on a vibrating source, he automatically deprives himself of a natural vibration isolator—his legs and feet—which isolate him very well from shock and from vibration frequencies above 1½ cps. The degree of isolation that can be achieved with a seat is a function of the dynamic characteristics of the seat. If the seat has a natural frequency coincident or close to that of the vehicle itself, the seat will be put in motion every time the vehicle is excited. This appears to be what occurs in most of the present-day vehicle seats; so that, rather than attenuating vibration and jolts, these seats tend to amplify vertical motion. Studies conducted on our vibration table and in the field have shown that man tends to vibrate from 50 to 400 percent (with the peak between 3 to 4 cps) more than the vibration table, or vehicle, between frequencies of 2 to 5 cps when seated on a standard seat cushion. These are from measurements taken at the base of the man's neck and the top of his head. Measurements at the belt line show a maximum of about 250 to 300 percent amplification.

Findings such as the foregoing led us to ask ourselves these questions: Does vibration in this range affect man's performance? How do these vibrations affect machine performance? How is the performance affected as a function of time exposed?

Under contract to the Office of the Surgeon General, Department of Army, we have recently completed the exploratory phase (using five volunteer subjects) of this project and are about to start our major testing program. These exploratory studies have given us trend data only and the results are not to be considered as conclusions but rather as grounds for hypotheses to be tested with a larger sample of 20 to 30 subjects. With this in mind, there appeared to be trends as follows: *(a)* Visual accuracy may be impaired up to 20 percent, *(b)* ability to perceive depth may be affected, *(c)* the ability to balance oneself may be impaired, *(d)* ability to track and keep constant foot pressure on a foot pedal shows greater error, and *(e)* reaction time may be increased. Whether or not these trends hold and become conclusions must await the analysis of data still to be collected.

There is much ground that is not covered in this paper that could well come under the heading of the psychological aspects of work efficiency.

Engineering Psychology

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more important characteristic in such control than variations in *force*. From this study and others, however, there is some evidence to suggest that, if the distance to be moved is short, the judgments of the operator are less accurate than when the distance of movement is longer. Further, cues derived from variations in force during very short movements can contribute to the accuracy of the judgment of the operator with respect to control of the device. Thus there seems to be some evidence to suggest that there should be some force variation in lever controls for the initial changes in lever movements, but that for larger changes there need be no particular resistance for the purpose of informing the operator when he has moved the lever far enough. Another study carried out by the Air Force is somewhat related to this topic(7). In this study it was found that when varying force with lever, wheel, and rudder controls, a certain amount of resistance can contribute to accuracy of operation, but above a certain degree (about 5 or 10 pounds) additional force is not necessary to obtain consistency of performance.

In connection with the operation of levers, we are presently doing some research to determine the reaction time of people in operating levers that are in different locations, such as forward, down, and above the operator's normal hand position.

As another example that deals with the design of control devices, many devices, such as levers, pedals, and switches, are operated without looking at them. Where two or more similar devices are used, there is a possibility of confusion. In aircraft, for example, there have been numerous proven accidents (some of them fatal) which have occurred because the pilot has used the wrong control device. This probably also has occurred with farm tractors. There are, however, ways in which the operator can be protected against the possibility of such errors. These methods include what is called "shape" and "location" coding of control devices. In connection with shape coding, for example, studies have been carried out to identify those designs of lever knobs which are not confused with each other by the sense of touch. Studies have also been conducted to determine the minimum distance between control devices that is safe in order to reduce errors in reaching for them.

These are but a few illustrative examples of research regarding human factors in equipment design. While these examples come from areas other than farm equipment design, they may at least suggest the potential applications of psychological research to farm-equipment design problems.

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Environmental Relationships of Plants and Animals

FOREWORD

The accompanying articles represent a summary or "State of the Art" report of scientific literature on the relation of plants and animals to their environments, contributed by the agricultural engineering members of the Technical Advisory Committee on Plant and Animal Husbandry, jointly sponsored by the American Society of Agricultural Engineers and the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. The joint committee was formed in 1957 to serve in a technical advisory capacity on projects conducted at the ASHRAE research laboratory in Cleveland.

It was decided at the time that the initial step in this cooperative activity would be an assessment by agricultural engineers of available knowledge of the relations of the production and well-being of plants and farm animals to their thermal environments.

It is important for the reader to understand, however, that only recently have engineers, to any extent, taken an active interest in this research field. While there is a great amount of literature describing experiments by physiologists, nutritionists, ecologists, biophysicists, and others, much of this is not reported in the accompanying articles because of conditions under which the tests were run or of other limitations. These compilations, gleaned from the best available research literature, are intended to serve mainly as a starting point for further investigations by research workers.

Committee members representing ASHRAE are: H. A. Lockhart (chairman), F. N. Andrews, T. E. Bond, A. W. Brant, and M. K. Fahnestock. Committee members representing ASAE are: C. F. Kelly (chairman), G. L. Nelson, R. E. Stewart, T. E. Bond, H. J. Thompson, and R. G. Yeck. Representation for ASAE for 1959-60 remains the same except for the addition of R. L. Givens and the appointment of R. E. Stewart as chairman.

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Function of Shelter in Plant Environments

Harold J. Thompson
Member ASAE

STUDIES of plant geography, plant ecology and plant physiology have illustrated the economic possibilities of modifying plant environments. Research techniques and practical application of the principles involved have necessitated the use of engineering methods. This report reviews some of the more basic environmental requirements and man's progress in providing shelter to meet these requirements.

Leach (14)* groups habitat or ecological factors under three headings, *i.e.*, climatic, physiographic (topographic and soil effects), and biotic. The latter includes activities of plants, animals and man. Moisture, temperature, light and wind are the predominant climatic factors studied. Other significant factors are gaseous exchanges, various dispersing mediums, diseases and insects.

Thermoperiodism, vernalization, aestivation, hibernation, heat sum, thermotaxis, Bergman's principle, Allen's rule are some of the temperature related terms used by ecologists (3 and 15). Following is a brief explanation of some of these terms:

Thermoperiodism is demonstrated most dramatically by the seasonal activities of plants; in fact, it is so commonplace that many casual observers never consider the matter in quantitative terms. For instance, some seeds require two consecutive cold seasons before germination: (3) ". . . Blueberries require an exposure of 800 hours to temperatures below 7 C before the dormant buds will develop;" or in coffee trees (20), "Although vegetative growth is optimal at 23 C day and 17 C night temperatures, the greatest number of flowerbuds are initiated at the highest temperatures (30 C day and 23 C night)." Daylight periods are sometimes referred to as photoperiods and night periods as skoto or nycto periods, *e.g.*, a nycto temperature would be a night temperature. With the advent of electric lights, light studies made better progress since most previous studies were based on observations under natural weather conditions or experiments with reduced light. Gardener and Allard (7) were among the first workers to study the effects of lengths of day and night.

Vernalization, in its most simple form, is the artificial temperature treatment of seeds to produce or inhibit growth. Phasic developments of some plants may require very exacting combinations and strict sequences of temperature, light, moisture, etc., *i.e.*, temperature treatment alone may not be sufficient. In wheat, sexual reproduction can be influenced by vernalization. Large-scale commercial attempts to vernalize small grains (perhaps 300,000 hectares) by Russians during the 1930's indicate interest at that time (17). However, this same writer attributes an earlier interest (prior to 1857) to an American, Klippart. The processes are so complicated that so-called "long day" plants can be made to grow like "short day" plants; others made to grow fast and not mature, others grow slow and mature fast, and still other grow fast and mature fast.

Aestivation and *hibernation*, terms usually associated with animals, are nevertheless also applicable to plant-life thermoperiodic functions. Aestivation is a state of dormancy caused by heat and drought,

Report prepared for the special use of the Technical Advisory Committee on Plant and Animal Husbandry jointly sponsored by the American Agricultural Engineers and the American Society of Heating and Air Conditioning Engineers, March 1958 (revised December 1958).

The author — HAROLD J. THOMPSON — is agricultural engineer (ARS), U.S. Department of Agriculture.

*Numbers in parentheses refer to the appended references.

or by either heat or drought. It is difficult to visualize the small amounts of energy required to maintain life in the smallest of seeds. In any event, the life span of the dormant plant or animal is limited because of this energy loss. Some animals have low limits for body temperature during hibernation.

Plants exposed to cold are of two categories, *i.e.,* those that freeze and those that do not freeze, in which case they stand the lowest temperatures attainable (16). Levitt's summary indicates that the larger the cell size, the easier the plant is damaged by frost and that, if plant juices can be undercooled to minus 20 F, then the plant will not be harmed by lower temperatures because contents "vitrify." However, such plants can be harmed by refreezing of parts during the thawing process. A better understanding of the freezing process would definitely speed up research on development of frost hardiness of plants.

"Heat sum," heat-unit theory, or degree-day concepts are of interest to growers wanting to meet definite harvest schedules (11). For instance, if a grower assumes that he wants a certain variety of sweet corn to mature on a certain date, seeds are planted according to a temperature calendar that will provide, say 1665 degree-days (F) above a base temperature of 50 F prior to harvest. During the growing season the grower may further alter schedules in accordance with actual temperatures. Care should be exercised in use of this apparently simple concept because of at least two controversial items; *i.e.,* optimum growing temperatures have not been established for many plants and because of the limitations of the degree day itself. Is it the time spent at the optimum temperature, or is it the amount of time spent either below or above the optimum temperature that influences rates of growth?

Control of plant migrations, seeding and growth by extremes of temperature, wind, and moisture is a fascinating subject in itself. For instance, in a plant community, a certain plant or tree will not be able to germinate well near the geographical limits of the environment, yet after germination, the plant may grow much better than those in similar stands having optimum environments for germination. Clarke's (3) illustrations indicate that some after scorching by fire, others boiling one hour or others exposed to −190 C for 3 hr, some seeds will still germinate.

Thermotaxis is the orientation of the individual plant with regard to the source of heat energy. *Bergman's principle* is the tendency of homeotherms to be larger within the same specie in the colder climates. Poikilothermous animals, such as reptiles and amphibians, exhibit the reverse relationship. *Allen's rule* indicates that animals may be of the same size but have less heat-dissipating surfaces in cold climates. Such principles are of limited application in plant work. The van't Hoff-Arrhenius law states that chemical reactions approximately double with every increase of approximately 10 C. Fortunately, Oosting's (15) statement that this law holds for photosynthesis between 41 and 77 F gives a temperature range somewhat similar to optimum greenhouse temperature ranges suggested by Went (20).

Many current and interesting research programs are now under way on the effect of light on plants. Furthermore, light is being treated as a scientific tool or variable in environmental research (in studying other climatic factors). Radiant-light energy effects are closely related to temperature or heat energy effects, since temperature is ultimately determined by solar radiation in nature. There are now many acres of commercial greenhouse space equipped to artificially control light, indicating the tremendous interest in the subject.

Photoperiodism assists in the control of flowering or reproductive processes of the plant whereas photosynthesis (total light used) determines the rate of growth of the plant.

Like thermotaxis, there are also such terms as "phototaxis, geotaxis and other tactic reactions"(3). Plant leaves and stems may be so arranged and shaped to receive the maximum or minimum amount of light. Trees furnish one of the most dramatic examples of reactions to sunlight. Forest vegetation will differ at various heights above the ground. Data on light penetration to the 3-ft level in a pine hardwood stand averaged only 6 percent of full sunlight (about 9500 footcandles being full sunlight)(15). Continuing he states: "Plants require much more light energy than they use, probably because of selectivity." Plants can also receive too much sunlight: "The production of chlorophyl . . . is perhaps more apt to become limiting or significant in high than in low intensities."

Light and moisture effects are definitely, though often indirectly, correlated. "Plants grown under shade conditions often show certain characteristics of anatomical structure, more particularly in their leaves, which distinguish them from plants grown in full sunlight. It must be noted, however, that many of these structural peculiarities are also to be found in the same plants when grown in full sunlight but in a moisture saturated atmosphere"(14). Root behavior is involved in the radiation, temperature, moisture complex, *e.g.,* change in soil temperature due to solar energy may not affect plant growth if soil humidity and moisture are at optimum levels. "Therefore, we can expect that the soil temperature controls plant growth when the root system is small, restricted or poorly aerated" — Went (20), with reference to tomatoes and potatoes.

Desert plants are of interest to those studying drought resistance in domestic plants (1). Rates of moisture transfer may be different on one side of a leaf than on the other side. Moving water from leaves to roots seems to be one of those fantastic reversals of nature's processes †.

Studies under laboratory or research conditions simulating outside conditions are further complicated by the effect of wind. Not only does wind change the evaporative rate from soil, but it also changes evaporation rates from the plants as well.

The Earhart Laboratory has not only made contributions to the solution of some of the air movement versus moisture problems, but it has also facilitated studies on root uptake of nutrients and moisture in the mist form, *i.e.,* the roots are merely suspended in air. Water uptake by roots and leaves from vapor in ambient air provides many problems of current interest, two of which are, first, the tension or water-transfer mechanism at the leaf or root surface and, second, the ambient psychrometric conditions under which such transfers take place. In a study of moisture transfer to and from leaves, in a near-saturated atmosphere, both microclimate and microtemperatures must be considered‡.

Air movement and wind may also affect gaseous exchanges of plants. Air turbulence in the Earhart Laboratory was found to increase uptake of CO_2 by tomato plants in sunlight.

$$CO_2 + H_2O \underset{\text{respiration}}{\overset{\text{light}}{\rightleftharpoons}} C_6H_{12}O_6 + O_2$$

Respiration processes continue throughout the 24 hr of the day, whereas photosynthesis processes can take place only during daylight. The intensity of the light required to equalize the rate of respiration of a species is called the compensation intensity (3). Therefore, if optimum use is to be made of factors such as winter sunlight, artificial light, CO_2, and perhaps even sugar solutions sprayed on leaves to compensate for lack of sunlight, some consideration should be given to the CO_2 stratification near the leaf surface. Wind studies by Went and others indicate that air movements above about 10 mph may be harmful to some plants. Wind can also cause changes in shape and form of plants and trees; in fact, it can be one of the critical factors in plant growth. Dessication, drafts (*i.e.,* localized chilling or heating), freezing, breakage of foliage, seed dispersion, etc., are all practical problems affected by wind.

Methods of modifying plant environments by the use of shelters are probably as old as the history of man. Greenhouse history indicates that some Europeans in the 1700's applied the term "orangeries" to structures with extra glass on sidewalls and roof to grow fruit trees and plants during cold weather (21). At the turn of the century the greenhouse was considered a luxury item available to few people. Today it is a more commonplace luxury item as well as a valuable tool for commercial growers. Europeans evidently think of a greenhouse as a structure in which plants grow with little or no artificial heat. If the house is heated, then it is a "glasshouse" — Gray, 1956 (8). The term "plant shelter" as used in this report refers to anything from the simplest shade, windbreak, coldframe, etc., on up to plastic and glass greenhouses.

The modern greenhouse construction industry can furnish many different types of structures, some even as packaged units, complete with engineering services and accessory equipment. The heating systems

†Discussion of S. Duvdevani's work at the Dew Research Station, Karkur, Israel, 1952 and 1953.

‡Microclimatology, i.e., the climate that immediately surrounds the plant or even portions of the plant, is sometimes confused with the term macroclimatology, i.e., climate for larger areas. The term "microtemperature," i.e., minute changes in temperature, might apply to either micro- or macroclimatology.

. . . Environment for Plants

offered for greenhouses are an indication of the "state of the art." However, basic research on the growing plant's requirements supported by engineering studies indicate that there are still many problems to solve. The variations in greenhouse techniques are numerous. Sprague (19) indicates some of the problems involved in forage crop research. Public institutions, growers, publishers and the construction trade provide much of the information needed. With the best of construction, however, one is reminded that the finest of greenhouses will not operate properly without good soil, plants and management. The remainder of this report will attempt to correlate some of the principles of plant responses and management practices with the engineering requirements in greenhouse construction.

Wright (21) presents many of the basic structural requirements of a glass-type greenhouse. Plastic glazed shelters differ somewhat in their structural requirements (12 and 4). Lawrence (13) gives problems to be considered in a major greenhouse reconstruction program undertaken by a research organization. Potter (18) also gives basic greenhouse management information for the person interested in greenhouse horticulture as a hobby or part-time adventure.

Some of the problems in greenhouse construction are similar to those inherent in constructing service buildings for any well-integrated farmstead. Location of an abundant supply of water, perhaps as much as 280 gal per 4-hr period per 1,000 sq ft of crops may be required (21). Use of evaporative coolers will also affect water requirements. Location of electric power for artificial lighting and equipment operation is necessary. If artificial light is required for plant growth, power consumption may be quite variable, depending upon lighting schedules and light intensity required for the plant's anticipated. Artificial light is not required during the cloudiest of days for most plants since intensities will probably not drop below 2,000 ft-c (footcandles) maximum (full sun is about 9,000), whereas artificial lights having intensities above about 1,000 ft-c are difficult to obtain, even under laboratory conditions. Atmospheric conditions and air pollution are to be considered since dirty glass may cut off as much as 10 to 20 percent of the light (13). Effects of smog during daytime in metropolitan areas of over 1,000,000 people are injurious to some plants (20). The use of electrostatic precipitators was ineffective against smog damage, whereas activated carbon filters proved beneficial. Yet many of our research and commercial greenhouses are located near such areas. With better transportation, roads and the higher prices of urban land, greenhouses may do well to move further from such metropolitan areas.

Natural surface drainage and type of heating system are two interrelated factors formerly considered in greenhouse layout when gravity-return piping was required for heating. With the use of pumps, circulators and higher pressure systems, the use of boiler pits, etc., are not required. Surface drainage is also important in meeting sanitation requirements. Other things being equal, areas requiring maximum use of winter sun should have houses located on southern slopes.

Types of soils to be encountered in footing design should receive special attention because most houses are of post sidewall construction, requiring firm support for glazed superstructures. Matters of additional houses, accessory buildings, house orientation, exposure to prevailing winds, are among other considerations. North and south-ridge alignments for even span houses is quite common; however, little difference in total light admitted will be found with east and west arrangement. Some growers prefer uneven spans for houses with east-west ridges, with a long span to the south.

Termite and other insect infestations should be given consideration in design of footings, foundations and framing members. Insects can be partially excluded by preventive measures such as proper use of reinforcing and expansion joints in concrete slabs and walls. Soil treatment under slabs, walkways and foundation walls, especially where cracks and other openings may or do occur, should not be overlooked, even after the best of structural precautions have been taken. Insecticides used should not be toxic to plant growth.

If possible, the greenhouse should have the same finish floor level as adjoining service structures. Tops of foundation walls should be level throughout the length of the house. Ridge and eave slope for longitudinal drainage of condensation, if required by greenhouse manufacturers, must be held to a minimum to prevent air stratification and drafts in long houses without partitions.

Framing for greenhouses should be well designed in accordance with dead load, live load and wind load requirements. Metal stresses used in design should be those commonly used by the metal buildings industries. The open-span type of house, without interior columns, is preferred by many growers. Open spans allow more flexibility in bench and planting arrangements.

Arrangements to suspend heating pipes, netting, blackout cloth, electrical conduit, lights, automatic ventilation machinery and ventilation sash must be considered. Some growers may elect to furnish their own pipes for columns and posts to support roof framing, in which case manufacturers can furnish a variety of fittings.

As much as 50 percent of the total light falling on a greenhouse may be lost due to shading by structural and glazing members, dirty glass and waste floor space used for walkways and floor-mounted equipment (13). Therefore, greenhouse design dictates that all sash, glazing bars, purlins and trusses offer the minimum of shading. The ideal structure would seem to be a transparent shell. The use of plastics for glazing purposes reduces dead load requirements but at the same time poses other problems.

Glasshouse manufacturers can furnish houses in various widths such as 10, 14, 18, 21, 25, 29, 32, 36, 40, 50, 60, 70, and 80 ft. Lengths are multiples of glass widths such as 16, 20, 24 and 28 in., 29 in. being quite common in present-day American construction. Trends seem to be toward wider glass and wider spacing between trusses. Some manufacturers use heat-treated glass in the wide sizes. Total house lengths of 150 ft are common, greater lengths sometimes being impractical due to wasted effort in caring for plants.

Usual roof slopes range from about 26 to 32 deg from the horizontal in even-span glasshouses. Roof pitch can affect the amount of solar radiation reflected by glass, *i.e.* normal incidence being the optimum. However, slopes made steep enough to receive full benefit of the winter sun will result in greater wind loads and higher convection losses. Cochran (4) reports that unheated plastic glazed slopes of 44 deg will shed snow in Utah. If the roof slope is below about 26 deg, condensation will not drain properly and may damage plants below. Condensation and its removal, heat loss, corrosion and deterioriation of glazing bars and glazing compounds, present challenging design problems. The use of aluminum alloys instead of wood for glazing bars, sills, eave rafters, etc., limits the use of whitewash and contact with other lime-bearing materials, such as mortar.

Plastic glazing apparently reduces air infiltration since more mechanical or sash ventilation is sometimes required when glass is replaced by plastic. However, extensive use is being made of plastics for temporary shelters. Kofranek and Kohl (12) estimate that California then had 40 acres of crops under plastic. Examples of structural practices given should stimulate the interest of agricultural engineers in horticultural structures. Durability of most plastic construction is much less than glass, but first costs of plastic construction are much lower. Flexible 0.002 and 0.004-in. thick plastic films and the more expensive rigid flat or corrugated sheets of plastic, reinforced with glass fibers, are in use.

Greenhouse heating, cooling and ventilation recommendations are numerous; however, the well-ventilated structure must be carefully designed. Heating and cooling systems, especially for nursery stock, are subject to critical design, because they must not fail, if adequate facilities and supplies are not available for immediate repair. Went's (20) cost analysis for an air-conditioned plant laboratory indicates some of the items to be considered and the costs involved if basic research is to be undertaken. Gray (8) reports many of the problems inherent in design of a good heating system. Size and shape of structure, prevailing winds, infiltration, glass area, design temperatures, solar heat load and fresh air requirements are typical items to be considered. Gray's report indicates practical locations of heating pipes to reduce drafts. Evidently drafts are more difficult to control in narrow houses.

Use of finned pipes and pressurized hot water systems are two of the more recent developments. Basic research by the National Institute of Agricultural Engineering (9) indicates many of the problems involved in glasshouse design. The potential use of electrical resistance heat in glasshouses is considered.

Equipment for soil sterilization utilizes steam, ordinarily at higher temperatures than levels required for house heating. (Chemical sterilization techniques are also

being developed.) Temperatures near 180 F are required for one hour to sterilize soil. Higher steam temperatures reduce time required to bring soil to the proper temperature, allow the use of higher sterilization temperatures and thus reduce both time involved and the leaching of soil nutrients. For this latter reason, chemicals, inorganic fertilizers, etc., are usually added after the soil has been sterilized.

The use of adequate ventilation for most summer greenhouse crops is mandatory; otherwise excessive temperatures and evaporation will reduce yields. Conventional shading to reduce solar-energy heat gain only defeats the primary purpose of a greenhouse, *i.e.,* it cuts down on sunlight. Therefore, it is not surprising that growers have been eager to adapt their houses to evaporative cooling using mechanical ventilation for crops grown in summer (5, 6 and 2). Both mist propagation and aspen-pad systems are in use. For pad systems:

- Approximately 7 cfm of air is needed for each square foot floor space
- Pads 2 in. thick should have areas adequate to hold velocities below about 150 fpm
- Water recirculation rates should be from ¼ to ½ gpm per lineal foot (horizontal) of padded area
- Makeup or replacement water required will of course vary with outside humidity and waste necessary to reduce salt concentration, but is sometimes estimated at 3 percent of the total amount circulated.

The use of baffles, divergence of airstreams, fan location, etc., are also to be considered. Several manufacturers are specializing in evaporative-cooling equipment for greenhouses. Evaporative cooling can also be accomplished by spray or mist nozzles within the houses. Carpenter (2) utilized nozzles delivering about 1.6 gal per hr at 60 psi. Mists can also be used during other seasons of the year to raise humidity. Both mist and fan-and-pad systems reduce watering requirements for plants and make it possible to admit more solar energy.

Another recent development is the use of dieldrin-impregnated cheesecloth screening in vents to reduce infiltration of very small insects such as thrips during summer ventilation (10). Resistance to air movement seems to be one of the problems in such systems depending upon natural ventilation.

Better shelters will be developed as fast as man can understand the real needs of plants and can coordinate such needs with practical, economical, well-engineered construction. More basic information is needed on energy exchanges between plants and their *natural* environments. Such information will aid engineers to design better shelters. Such studies should not be undertaken at the expense of sound, long range breeding and genetic programs for both natural and sheltered environments. Such measures and programs should supplement each other. Engineers should continue their search for better materials and methods to provide adequate shelters and mechanize the activities therein.

Much of the future development of plant shelters depends upon the price we are willing and able to pay for fuel or energy to regulate the environment. If abundant energy is made available, only our lack of imagination or space can limit plant production, and thus our primary source of food, fiber and many of the most beautiful things in nature.

TABLE 1. CONSTRUCTION COSTS OF THE EARHART PLANT RESEARCH LABORATORY, INDICATING THE PROPORTION BETWEEN GENERAL CONSTRUCTION AND SPECIAL FEATURE COSTS

(Includes the original $407,000.00 gift from the Earhart Foundation and later appropriations of over $15,000)

	General construction	Special features
Concrete, framework and finishing	$133,636.60	
Roofing	7,311.00	
Metal floors		$ 11,874.00
Fumigation entrance and sterilizer		4,495.00
Power and general lighting	30,700.30	14,000.00
Fluorescent light panels		16,734.00
Motor generator		2,000.00
Control panel and time clocks		3,000.00
Recorders for temperature and CO_2		3,500.00
Refrigeration and air conditioning		118,475.50
Water treatment		13,168.00
Plumbing	2,707.00	
Smog filters		3,285.00
Wind and fog equipment		1,400.00
Automatic sprinklers	6,096.00	
Plans and supervision	20,000.00	6,000.00
Insurance, legal fees, etc.	3,500.00	
Furniture, trucks, etc.	3,900.00	7,000.00
Miscellaneous	5,000.00	5,000.00
Total	$212,850.90	$209,571.50

NOTE: From Went (20), chapter 26. Chapter 1 gives resulting floor space of 4,584 sq ft for controlled-temperature growing space (original Clark greenhouse space of 448 sq ft probably not included); temperature control facilities 4,000 sq ft; space required for handling plants, 2,200 sq ft, and offices and other facilities, 2,800 sq ft.

TABLE 2. SIZE GROUPS OF GLASSHOUSES IN ENGLAND AND WALES

Size group, acres	Number of holdings	Glasshouse area, acres
Under ⅛	9,545	565
From ⅛ to ¼	2,891	509
From ¼ to ½	1,675	586
From ½ to 1	961	669
From 1 to 3	608	990
From 3 to 5	110	422
5 and over	91	921
Total	15,881	4,662

TABLE 3. AREAS OF GLASSHOUSES IN VARIOUS COUNTRIES

Country		Area of glass in acres	Country		Area of glass in acres
Europe:	Holland	8,030	North America:	USA	5,070
	Britain	4,700		Canada	740
	Belgium	1,880		Others	25
	Germany	2,440	Total		5,835
	Denmark	860	Asia:	Japan	220
	Sweden	1,210		China	75
	Norway	500		Others	50
	Switzerland	320	Total		345
	France	500	S. Hemisphere:	S. America	25
	Russia	2,200		S. Africa	25
	Others	750		Australia	25
Total		23,390	Total		75

Tables 2 and 3 are from "The Heating Problems of Glasshouses — I," by E. R. Hoare, head, horticultural engineering department, National Institute of Agricultural Engineering (England), published in *Industrial Heating Engineer,* 18 (130), September, 1956.

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Environmental Requirements for Poultry Shelter Design

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THIS report deals with laying hens and the laying flock in general. Application to broilers will be similar to that for layers in most respects, except that the size of the bird considered is different. In attempting to collect data on poultry that would be of use to engineers for design purposes, it was found that the greater part of the work had been done under basal conditions. This made it necessary to attempt to correct these basal measurements to conditions as they actually exist in the field.

This report should not be considered complete, as there is much late work which is not included because of space limitations. The authors believe, however, that the report contains typical design figures which will aid the designer.

Heat Production

In general, the particular condition under which heat-production measurements were taken was to confine the bird in a small pen in such a way as to restrict movement as much as possible without making the bird unduly uncomfortable. All birds were usually measured after fasting from 24 to 48 hr. In some instances they were housed in totally dark containers, and in others the boxes were transparent so as to allow the experimenter to observe the activity of the bird.

The total heat production of the chicken can be broken down into three parts. The first part to be considered will be heat produced under basal conditions. Following this, the bird is fed and heat determined which should be added to the basal heat as the heat increment of feeding. The last consideration will be to make some estimates of the heat produced by the activity of the bird. The addition of these three heat values will give the total heat produced by the chicken under farm conditions.

The majority of the investigators, whose results were consulted, except for two or three who have made comprehensive and systematic studies, have produced work which has been fragmentary. The number of birds used in these experiments has been small. Also, as will be brought out later on in this report, the same bird used under the same conditions at several different dates gave results which were quite variable. Only one investigator has made a sizeable contribution to the values of basal heat produced under different environmental temperatures (2, 3)*. The remaining workers used a constant temperature for their work, usually selected as that of thermoneutrality, or what is sometimes called the "critical temperature."

Mitchell and Haines (8) in one of their earlier experiments determined the environmental temperature for thermoneutrality as 16.5 C or 62 F. The data that these investigators used for their calculations were re-evaluated by Barott and Pringle (2) and it was determined that these data gave the thermoneutral temperature somewhere between 75 and 80 F. This temperature was that obtained as the minimum heat output of 12 Rhode Island Red hens under fasting conditions. Several other experimenters have confirmed the temperature of between 75 and 80 F as the minimum heat-production temperature under basal conditions of the adult bird. Thus it seems possible to use this value even though the number of experiments in its determination were small.

The basal heat values recorded were in general as numerous as the number of experimenters recording them. Several references were found where the birds used had been fed shortly before being placed in the calorimeter. Thus the values recorded were not actually basal conditions but also contained a portion of heat due to the feed. Mitchell and Kelley (9) recorded a value of approximately 40 Btu per hour for 4-lb nonlaying hens, both Rhode Island Red and White Plymouth Rock, at an environmental temperature of 82 F. The birds at this time were being maintained on feed containing about 72 grams of dry matter per day equivalent to 80 grams of wheat and had some freedom of movement. In an earlier experiment (8) the basal rate for 28 nonlaying Rhode Island Red hens weighing about 4½ lb was determined as 18½ Btu per hour. The environmental temperature used for these experiments was 65 F.

In experiments by Barrott and Pringle (3), using Rhode Island Red hens, the basal rate for a 5-lb laying hen was determined as 25 Btu per hour at an environmental temperature of 60 to 80 F and 20 Btu per hr for a 4-lb hen. Other data recorded at this time gives the heat produced by a 5-lb bird at 40 F as about 29 Btu per hour and 23 Btu per hour for a 4-lb bird. These results are shown graphically by Fig. 1. The hens used for these experiments were housed under normal conditions and were brought into the test chamber early in the morning and kept in complete darkness without food and water during the 24-hr period of the investigation. This type of experiment would seem to give more valid results for our use than any of the others studied.

One of the tables presented by Benedict (4) included several values for birds which had eaten within several hours of being placed in the chamber. These values have been separated from the main table and are reproduced as Table 1 in this report. The heat values were measured five different times using three different hens. The average value obtained for these 3½-lb birds at a temperature between 70 and 75 F was about 30 Btu per hour, which would correspond to about 35 Btu per hr for a 4-lb bird by a proportional increase. Considering that these five birds were confined, this value agrees well with the data of Mitchell and Kelley reported earlier. The important point about this table is the variation which appeared in the one bird that was tested three times. If the test is considered as valid, then it must be that no chicken will ever give the same heat output twice when the conditions have been duplicated, keeping in mind that these are not basal tests in this case. The low value was 29 Btu per hr and the high value was 37½ Btu per hr for this particular bird, number 52. It was also found that the basal heat output of fasting hens was not significantly affected by different environmental temperatures in the range of 60 to 80 F.

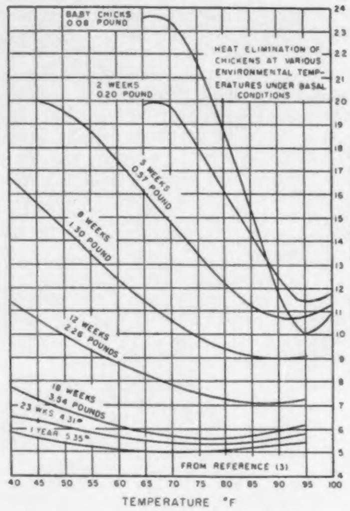

Fig. 1 Heat elimination of chickens at various temperatures under basal conditions

Corrections need not be applied to the above work recorded by Benedict and by Mitchell and Kelley to increase the heat output to allow for the increment due to feeding. It will be interesting to apply the heat of feed to the basal rates to see if the results will check with those already obtained for non-fasting conditions. In a check on the heat content of feed consumed by laying hens, two laying hens weighing about 4¼-lb under winter conditions consumed about 11 Btu of feed per hour for each hen (4). When this is added to the basal rate for a same size hen, approximately 23 Btu per hr, the results are 34 Btu per hr for a confined laying hen. Thus the heat content of the feed added to the basal heat rate will give results which are comparable to actually recorded values.

Report prepared for the special use of the Technical Advisory Committee on Plant and Animal Husbandry jointly sponsored by the American Society of Agricultural Engineers and the American Society of Heating and Air Conditioning Engineers, March 1958 (revised December 1958).

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*Numbers in parentheses refer to appended references.

TABLE 1. HEAT PRODUCTION OF FIVE HENS IN BTU PER HOUR SOON AFTER FEEDING

(From reference 1)

Bird No.	Weight lb	Time after feeding	Environment temp. deg F	Btu per hour
52	3.70	2-3 hr.	75.3	37.5
52	3.70	0	72.0	33.8
54	3.74	?	71.0	28.5
52	3.56	12 min	70.9	28.0
59	2.92	22 min	73.8	23.0
Average	3.53		72.6	30.3

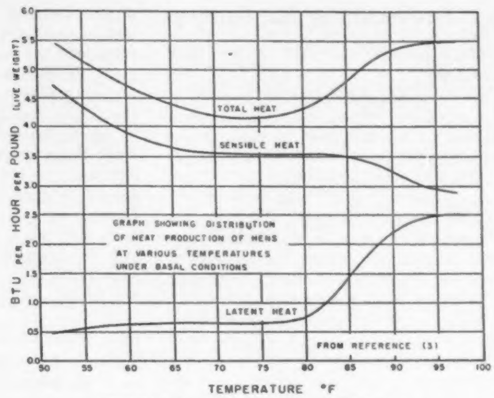

Fig. 2 Heat production (basal) of hens

Another refinement can be taken into consideration for the recorded value of 40 Btu per hr for a non-laying hen being fed with some freedom of movement. It is stated that for a 50 percent egg-laying rate two more additional Btu per hour are given off (9). If this hen starts laying at the 50 percent rate, it will then give off 42 Btu per hr.

The final correction to be made on the above values is the addition of heat given off by movement. Most of the workers noted during the course of their experiments a diurnal rhythm during fasting with the maximum occurring about 8:00 a.m. and the minimum occurring at 8:00 p.m. Some of the workers attributed this diurnal rhythm to the activity of the chicken since it was observed to be twice as active during the morning hours as it was in the afternoon and evening. A study was made (7) to determine whether the diurnal rhythm of metabolism was caused entirely by differences in visible activity or whether some more fundamental phenomenon was also involved. The results indicated that the 9 percent increase in heat for the morning periods was exclusive of activity.

Other data was recorded which gives some values of heat production for activity (7). The results concluded that a hen will give off 45 percent more energy when standing than sitting and since a hen is active about 13 hr out of the day, the total heat value for basal plus feed should be increased by about 25 percent. If this increase from activity is added to the 34 Btu per hr accumulated so far as the sum of basal heat and heat increment of feeding, the final total heat value produced by a 4-lb laying hen under actual conditions will be 43 Btu per hour.

It is also stated that the extra heat produced due to activity can be estimated by assuming it equal to approximately one-half the basal heat value (9). Whether a basal heat of 18½ Btu per hr or 20 Btu per hr is used, the final total heat produced including basal, feed and activity rates by a 4-lb laying hen under actual conditions at 40 F will be approximately 44 Btu per hr. This is in close agreement with the value given in the preceeding paragraph.

Since the final results have been compiled from several sources and various test conditions, it is probable that a value for total heat production at 40 F rounded off to 45 Btu per hr per 4-lb laying hen would be entirely satisfactory. Parker (12) used in his ventilation studies a total heat production by 4-lb laying hens of 45.4 Btu per hr which he derived from the formula: Btu per hr $=$ 16.4 (pounds live weight)$^{0.734}$. This adds more strength to the suggested value of 45 Btu per hr as a value for 4-lb laying hens at an environmental temperature of 40 F.

Moisture Production of the Hen

Of equal importance to the heat output of the laying hen is the moisture given off by the hens. Moisture is produced by three different methods: vapor in the expired air, moisture in the droppings, and diffusion of moisture through the body of the hen. The last method noted has only recently been considered as important enough to warrant further investigation. Since no estimates of the amount of moisture which passes through the skin is available, no attempt will be made to apply any corrections for it. Future investigation should show the extent of this source of moisture. The other two methods of moisture production by hens are better understood and more work arriving at acceptable results has been accomplished.

The first method of moisture production to be discussed in this report will be respired moisture. The heat values which were calculated earlier in the report were for total heat, and, therefore, before being used have to be corrected to available or sensible heat since part of the heat given off by the birds is in the latent heat of respired moisture. The graph in Fig. 2 indicates the amount of heat that is contained in the respired vapor as latent heat (2). The amount is relatively constant until the temperature of 80 F is reached, the upper limit of the thermoneutrality zone, when it rapidly increases up to about 90 F. After this temperature the amount of increase slows down indicating a breakdown in the heating mechanism of the chicken. Variation of the humidity will also affect the amount of the latent heat, but there was no indication as to what extent this occurred. The formula $W = 14e^{0.06435t}$ has been suggested for the determination of the percent of total heat appearing as latent heat (9). In this formula, t is the environmental temperature in degrees centrigrade. The result of this formula is shown by Fig. 3 where latent heat as a percent total heat is plotted against the environmental temperature in degrees Fahrenheit. Also shown on the same graph is the percent of total heat appearing as latent heat calculated from the values in Fig. 2. The true value will probably lie somewhere between these two lines since the experi-

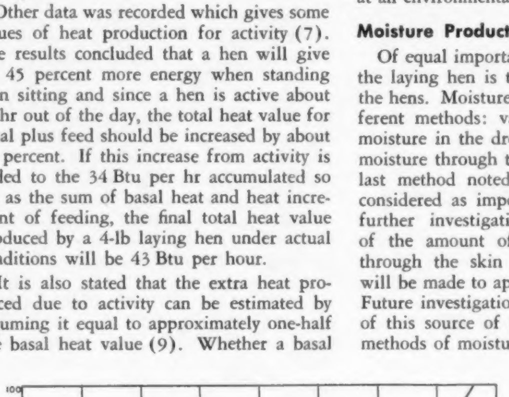

Fig. 3 Values of latent heat as percent of total heat

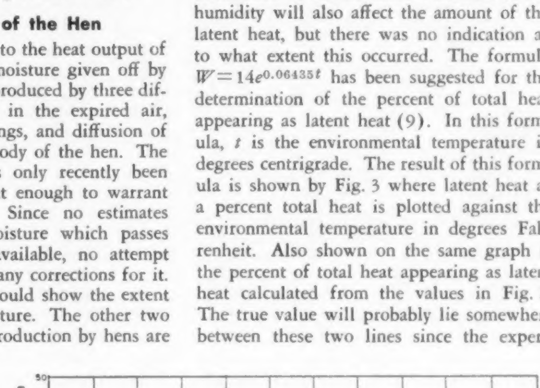

Fig. 4 Grams of moisture (basal) respired per hour

mental data was obtained under basal conditions.

The amount of water actually respired by the hens can be arrived at by several methods. Fig. 4 is a graph showing the grains of moisture respired per hour for different ages of chickens and temperatures (3). These data were taken by direct measurement during basal metabolism tests. Dividing the total amount of latent heat at the environmental temperature which the amount of moisture is desired, by the heat of vaporization of water at 82 F, which is the average skin temperature, will give a calculated value of the moisture produced (9). It seems more likely that the temperature used for the heat of vaporization should be that of the body, 106 F, instead of skin temperature. Most authors writing on ventilation of poultry houses usually use the moisture of respiration at a temperature of 30 to 40 F for a 4-lb hen as about 20 grains of water vapor per hour, or 0.07 lb per day.

The third source of moisture from the chicken is in the droppings produced. The amount of droppings is usually about 20 percent of the dry matter content of the feed fed. Of the droppings, about 75 percent is moisture. A flock of 100 layers under actual conditions will void about 38 lb of droppings daily which would mean almost 30 lb of water per day in the droppings (5). This amount will vary with the size of the birds in the flock, the value given for the 4-lb hen, while the amount for 100 6-lb hens would be close to 40 lb of water per day. If no moisture in the droppings were removed by evaporation or by ventilation, but all had to be absorbed, about 12 lb of litter per hen per month would be needed which by the end of the year would build up better than two feet deep.

The total amount of moisture given off by the hens is thus about as variable as the heat produced. The addition of the moisture in the respired air to that in the droppings will give about 38 lb of water produced by 100 4-lb hens and that produced by 100 6-lb hens, approximately 50 lb.

With a good approximation of the total heat and water output of a layer, it is possible to consider design requirements for its housing. The majority of the buildings used for the housing of poultry in the United States was not built to allow full use of the heat output of the laying hen. Only those poultrymen who are willing to invest some capital in the laying house will be able to make use of the heat produced by the hen, and those that do invest will get a good percent return on their investment.

The possible effects of humidity on chickens should be mentioned before continuing with the design requirements of poultry shelters. Low humidities were not recorded as having any adverse effects on chickens but the same is not true for high humidities. This becomes even more important when the high humidities are coupled with high temperatures. At high temperatures chickens have to pant to eliminate water, but this panting in turn creates more energy that has to be disposed of. With reference to Fig. 3, below the temperature of 80 F the amount of heat given off in the expired air is small and almost constant, but above 80 F the rate increases rapidly to 90 F and then starts to level off. By varying the relative humidity at these high temperatures, it was found (2) that adult chickens will survive at 100 F if the humidity is below 30 percent. For a temperature of 95 F, the humidity should be below 60 percent, and at 90 F below 75 percent. If the relative humidity becomes higher than that indicated for a particular temperature, the hen will not be able to dissipate enough heat by vaporization which will result in heat prostration and death.

Heat Balance On A Poultry House

The heat balance on a poultry house as with any other structure can be written as heat in equals heat out. The first part, heat in, must take into account all the heat sources in the poultry house. It will include the heat production of the hens, heat equivalent of all the electrical appliances and lights used, heat generated in the litter, and heat due to solar energy. The heat production of the hens available for heating the structure has been discussed earlier in this report. In general 25 hens require more floor space than one cow but give off only one-third the amount of heat. Also the poultry house is not exactly tailored to the chicken since they definitely do not require 7 ft of head room. Since the space is large compared to the size of the animal, every source of heat becomes increasingly important. Their importance, however, does not make them any easier to compute. The electrical equivalent of heat is easy to compute, but it generally adds only a small amount, in most cases consisting of a few lights and several small motors on the ventilating fans or mechanical feeders.

If the building is properly oriented, a large amount of heat can be gained from the sun in the form of solar energy. This gain can vary from 15 Btu per hr per square foot of glass to 30 Btu per hr per square foot of glass depending upon location, cloudiness, season, cleanliness of glass, etc. (16). It should be kept in mind that all of this gain will come during the daylight hours, and during the night the same windows that let in heat during the day will lose heat. This heat loss through the windows can be reduced by double glazing or the use of storm windows which would almost double the heat retention in the building. For all south-facing windows under average conditions, the heat gain by solar radiation will always be greater than the heat loss through the glass whether the windows are single or double glass.

The amount of heat supplied by the decomposition of deep litter is the hardest quantity to account for. Only one reference was found which tried to account for this source (16) and the amount recorded was found by determining all other parts of the heat balance equation and solving for the heat of decomposition. The values used were under actual operating conditions in an insulated 24 x 24-ft pen in a larger building and the heat furnished by the decomposition of the litter amounted to about one-fourth of that furnished by the birds, or 10 to 12 Btu per hr per bird.

The heat outside of the heat balance equation will contain such factors as heat loss through the walls and ceiling, heat loss through the windows including crack leakage, the amount of heat lost through the ventilation system and the production of latent heat. Most of these losses can be obtained readily from handbooks and thus usually offer no problem when solving the heat-balance equation. To utilize fully the small amount of heat gains in the poultry house, the heat loss side of the equation must also be kept small which can be done only by proper insulation of the building. External factors which should be considered are the possible use of windbreaks to reduce the amount of air flow around the building during the winter months and the use of shade trees during the summer. When mechanical ventilation is beng used, there is no need for ventilating windows. The heat loss can thus be reduced by using fixed windows which will considerably reduce the amount of crack leakage.

Ventilation for the Poultry House

The ventilation system of the poultry house should take into consideration both the winter and the summer ventilation requirements. The main objectives of ventilation during the winter months are to keep the moisture content of the litter down to 35 to 40 percent, to keep to a minimum the ammonia fumes and other odors, to reduce the temperature fluctuations to a minimum, and to help eliminate condensation on the walls and ceiling. During the summer months, ventilation is needed to help relieve the build-up of heat in the building, and to keep a constant movement of air around the hens to aid evaporative cooling processes.

The methods of ventilation of poultry houses can be divided into two classes, either natural or forced ventilation. Natural ventilation is an economy means and the construction of the building is usually in keeping with the ventilation system. Openings are provided in the south wall with the possibility of covering the openings with burlap or glass during inclement weather (18). Such a method if properly constructed will accomplish everything except the reduction of temperature fluctuations. Since the building is open, the temperature will be only several degrees warmer than the outside air and will vary with the outside temperatures (13). During the summer months the results with either method of ventilation will be approximately the same as long as there is sufficient air movement for the natural system.

Controlling the amount of ventilation by the use of fans and thermostats is more in line with engineering work. Most of the fans are installed to operate as exhaust fans and it is considered desirable to use either a two-speed fan or two separate fans. This will allow for a variation in the rate of ventilation and make it possible to have an almost continuous air circulation. The rates which have been acceptable for engineering work are about 1 to 1½ cfm per bird for the low-speed amount and 3 to 4 cfm for the high-speed amount (10). The high speed amount will be used when the outdoor temperature is high with respect to the

indoor temperature which is usually held to 35 to 40 F during the winter months. The operation of the low-speed unit is continuous and would be turned off only during extremely cold weather to conserve heat. By placing a thermostat control on the high-speed fan, its operation can be made automatic thus almost guaranteeing the proper indoor conditions.

The above suggested ventilation rates depend upon such factors as the heat loss from the building, the amount of heat produced in the building, the desired indoor temperature and humidity, the design outdoor temperature and humidity, and other factors of equal or less importance. To consider all these factors greatly complicates the design of the ventilation system, but for a proper installation they must all be considered. Parker (12) has constructed two nomographs which can be used in the field for rapid design of poultry laying-house ventilating systems. These nomographs along with the design data he presents greatly simplify the ventilation problem.

Space Requirements

The space requirements for laying hens have been based in the past only upon experience and observation. Until recently no actual tests have been made as to the space truly required. Table 2 shows the values which have long been used to determine the space needed (1). This table takes into account that, if the bird density is as indicated, it will reduce cannibalistic tendencies, keep the litter moisture content low, etc.

TABLE 2. SPACE REQUIREMENTS FOR HENS IN PENS
(From reference 1)

Small Breeds		Large Breeds	
Number	Area sq ft	Number	Area sq ft
25	4	25	4½
100	3½	100	4
200	3	200	3½
400	2¾	400	3¼

In the experimental solar hen house at Pennsylvania State College (5) tests are now being conducted to determine how much room is actually needed for laying hens. The bird density has been increased by 400 percent without seriously affecting the laying rate of the hens. A high degree of mechanization is also being used. An automatic feeder built four tiers high is located along with the waterers and roost over a mechanical droppings-pit cleaner thus making it possible to remove about 75 percent of the total droppings. This along with the large solar heat intake of the building makes the litter dry with bird populations of less than one per square foot. The cost of such a building with all the mechanical equipment included is only $4.50 per bird at that high population, which is comparable to a more commonly constructed poultry building, and greatly simplifies the labor requirements. Perhaps the results of these tests will show a new approach to the housing requirements of poultry.

Feed Requirements

A flock of 300 good layers will eat about 10 tons of feed a year (17); thus it is essential for efficient production to keep the feed nearby to reduce the time consumed in feeding the hens. On most existing poultry enterprises, the time spent in feeding, watering and egg-gathering labor can be reduced by 50 percent by enlarging the pens, removing partitions and rearranging equipment. Larger pens mean that more mechanical equipment can be used. In the development of mechanical feeders, the continuous drag-chain type seems to have been given the most attention (15). With this type of feeder, a 60-ft length will handle approximately 700 White Leghorn layers, providing a feeding space of 2 in. per hen along each side of the feeder. Automatic waterers are also essential and should be so constructed to reduce the amount of spillage to a minimum. If there is a chance of the temperature in the house going below freezing during the winter, the waterer should be provided with an electric heating wire to prevent breakage of the pipes.

The extent to which poultry mechanization can take place is almost unlimited. Plans have been developed for an automatic egg machine (11), where once a week the farmer will go to the building housing the unit, take a quick check of the controls and place the crates of eggs, already cleaned, sorted and graded, in his truck to take them to market.

Feed requirements of laying hens may be broken down as shown in Table 3.

TABLE 3. FEED REQUIRED BY CHICKENS OF DIFFERENT LIVE WEIGHTS FOR MAINTENANCE AND FOR THE PRODUCTION OF 0, 100, 200, AND 300 EGGS, RESPECTIVELY, PER YEAR
(From reference 21)

Average live weight	Average Total Feed Required per Hen per Year, in Pounds: 0 Eggs per year	100 Eggs per year	200 Eggs per year	300 Eggs per year
4.0	57	71	85	99
4.5	61	75	89	104
5.0	65	80	94	108
5.5	70	84	98	112
6.0	74	88	102	116
6.5	78	92	106	120
7.0	81	96	110	124
8.0	89	103	118	132

Optimum Temperatures

The work of Ota *et al* (19) indicates that the optimum temperature for egg production is in the range 50-60 F (5 to 16 Rhode Island Reds). Increasing temperature causes decreasing production. Low temperature is not particularly harmful unless low enough to freeze the comb and wattles.

Baby chicks are commonly started at 95 F when one day old; the temperature is then dropped 5 deg per week until 70 F is reached. This control of temperature is furnished by a brooder of some type.

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Environmental Research with Dairy Cattle

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INVESTIGATIONS concerning the effect of environment on cattle fall in two general categories, field studies and laboratory studies. Findlay (21)* summarized the results from approximately 100 references concerning the effects of environment on farm animals and this report involved the review of some 180 more references. Most were obtained from the "Bibliography of Agriculture." These references by no means represented all research work in the field. Some references were not available to the reviewer; others probably were obscured by misleading titles, and, of course, results of some studies have not been published.

Effect of Climate On Milk Production

Hancock (28) wrote an excellent review of literature concerning the effect of climate on milk production. He divided the literature into that which concerned the effect of low temperatures and into that which concerned the effect of high temperatures. He also differentiated between field studies and psychrometric room studies by treating each as separate subheadings under the two temperature headings.

Field studies concerning the effect of cold on milk production were somewhat contradictory. Hancock's report lists Davis (13), Popoff (64), Kelley and Rupel (42), and Sementovskaya and Garkavi (79) as reporting losses in milk production at low temperatures. The latter reference reported a 26 percent loss in milk yield but that this loss was prevented through supplementary feeding. The reports of Buckley (10), Dice (15, 16), and Witzel and Barrett (94) indicated no milk production losses with cold. The latter reported results from an open-pen barn wherein air temperatures dropped as low as −20 F.

Studies at the Psychroenergetic Laboratory (Ragsdale *et al,* 67, 68) showed a breed difference in regard to cold tolerance. The Holstein cattle withstood continuous exposure to temperatures as low as 10 F without a decline in milk production. Jersey's production, on the other hand, began to drop at 30 F. Hays (30) in a short-term experiment with controlled temperature conditions and with two unacclimated Jersey cows found that a drop in temperature from 61 to 27 F increased butterfat percentage from 5.4 to 6.0 percent. The psychroenergetic studies (12 and 57) also showed increased percentages of butterfat at temperatures below freezing. Solids-not-fat among both Holsteins and Jerseys and lactose among Jerseys decreased with cold, but total nitrogen increased with low temperatures. Other constituents were hardly influenced.

Ragsdale *et al* (70) reported no change in milk production that could be attributed to humidity at 11 to 17 F air temperatures. Relative humidities in those tests ranged from 62 to 84 percent. Brody *et al* (6) reported no significant effect of up to 10-mph winds on milk production at 18 and 50 F. Brody *et al* (7) observed no effect of radiation (from fluorescent and incandescent lamps) on milk production at 45 F. Radiation was continuous for one week at each of several levels up to 180 Btu per sq ft per hr.

The effects of high temperatures on milk production and composition that were observed in most field studies were generally confounded by seasonal changes in feed. However, Speir (80) noted lower milk yields and butterfat contents with barn temperatures above 50 F. Kelley and Rupel (42) with Guernsey and Holstein cows concluded that an optimum stable temperature would be about 50 F and reported that temperatures up to 65 F slightly increased production but reduced butterfat. Haarlass (26) observed similar results in a double reversal trial was 18 Dutch Friesian cows. He concluded that 50 to 60 F stable temperatures were optimum. Hancock and Payne (27) with six sets of identical twin calves that were split between Fiji (average maximum temperature equal 85 F) and New Zealand (65 F) found markedly lower production among the cows that were reared and milked in Fiji. All were fed identical diets. Considerable variation among sets of twins was observed.

Hancock (28) lists the following as reporting, as a result of field studies or surveys, a depression of butterfat during summer months: Eckles (18), Ragsdale and Turner (65), Weaver and Matthews (91), Brooks (9), Houston and Hale (33), Jacobson (35), Heinemann (31), and Davis *et al* (14). Some of these investigators also studied the solids-not-fat content of milk and found it lower during summer months. Studies in controlled-temperature rooms also clearly indicate that high temperatures depress butterfat and solids-not-fat—Cobble and Herman (12), and Merilan and Bower (57).

A dramatic effect of high temperatures on milk production is given by Espe (20) who cited the loss in milk production of a record-producing Holstein cow (which established a world record in 1942) during a heat wave while she was on exhibition in Seattle, Wash. With no change in her ration, her production dropped from 142 to 98 lb per day during the heat wave and stayed there for 5 days. Ten days after the return of cooler weather her production rose to 131 lb per day.

Controlled environmental conditions as provided by climatic or psychrometric rooms are considered most desirable for the study of the effect of high temperature on milk production. Hancock (28) quoted experiments by Hays (30), Bartlett (1), Regan and Richardson (71), Riek and Lee (74), and Lee (52) but placed major emphasis on the results of work at the psychroenergetic laboratory at Columbia, Mo., Ragsdale *et al* (66, 67, 68, and 69). The psychroenergetic laboratory studies although limited to 12 cows in each test had several tests within the zone of high temperatures. These studies clearly indicated that high temperatures depressed milk production. They further showed that high humidities—Ragsdale *et al* (70)—accentuated the deleterious effects of high temperatures. The production losses with continuous exposure to 95 F and 45 percent relative humidity were about the same as they were in a similar test at 85 F and 90 percent relative humidity. Holstein production dropped about 30 percent, Jersey about 25 percent, and Brown Swiss about 20 percent. Brody *et al* (6) reported very little benefit from wind at 80 F but definite benefits at 95 F in studies that followed the humidity test. Working with individual production records of the 3 Brown Swiss, 3 Holstein, and 3 Jersey cows of this experiment, and making an estimate of the normal lactation decline, 5 and 10 mph winds were noted as recovering 10 percent of normal milk production that was otherwise lost during continuous exposure to an 85 F temperature and 65 percent relative humidity (air velocity equal 0.5 mph). The 5 and 10 mph winds were even more beneficial at 95 F.

Radiation as provided by incandescent and fluorescent lamps (simulating solar heat) in the psychroenergetic laboratory was reported by Brody *et al* (7) as also accentuating the deleterious effects of high temperatures. Continuous exposure to a radiation level of 180 Btu per sq ft per hr caused a decline in milk production at temperatures as low as 70 F.

The foregoing psychroenergetic laboratory studies were under constant temperature conditions. Later tests in this laboratory, Brody *et al* (8), showed that diurnal temperature ranges, much like those that might be found in various areas of the world, were comparable to the effects under constant temperature conditions, the average temperature during the diurnal being used for purposes of comparison. A daily range of 70 to 100 F (average temperature, 85 F) had an effect on milk production similar to that experienced at 85 F constant temperature. Of interest was the fact that a 50 to 110 F diurnal (average temperature equal 78 F) was less deleterious than the 70 to 100 F diurnal cycle and that a 40 to 110 F cycle (average temperature equal 66 F) appeared to cause very little drop in milk production.

The Louisiana Agricultural Experiment Station has compared animal reactions under field conditions with those in a controlled-temperature environment. Johnston *et al* (39) reported that 10 Holstein cows held in a con-

Report prepared for the special use of the Technical Advisory Committee on Plant and Animal Husbandry jointly sponsored by the American Society of Agricultural Engineers and the American Society of Heating and Air Conditioning Engineers, March 1958 (revised December 1958).

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*Numbers in parentheses refer to appended references.

trolled temperature room for 8 hr each day at 82 F and 21 mm of Hg vapor pressure did better than two other groups of 10 Holsteins each that remained outside. Shades were available to the outside groups. The average outside maximum temperature during the test was 92 F (vapor pressure equal 18 mm Hg). All animals were together on the same night pasture and received chopped green forage or silage during the day. In another test, Vizinat *et al* (89) reported that repeated alternate exposures to two weeks at high temperatures (95 F for 8 hr during the daytime and 75 F for the remainder of the day) followed by two weeks at a cool temperature (75 F, vapor pressure equal 25 mm Hg) caused losses in weight and milk production among Holsteins but not among Holstein-Sindhi crossbreds.

The foregoing would indicate that cross breeding for heat tolerance might be the solution to the problem of high temperatures. However, the level of production is generally low among heat-tolerant Indian and African breeds—Joshi and Phillips (40), Joshi *et al* (41). The over-all level of production of their progeny is generally lower than that of European breeds with which they are crossed. Frye *et al* (24) reported such an experience with Red Sindhi-Holstein (F_1) cows. They pointed out that selection for production was very limited.

Shades have been found beneficial for beef animals, Ittner and Kelly (34), and are used by many dairymen. Rusoff *et al* (75) found that sprinkling plus shade was correlated with greater milk production than was observed under shade alone. Tests were conducted about two months during each of three summers. Both reversal and continuous types of experimental designs were used. The production of Holstein cows with shade plus sprinkling ranged from 0.8 to 5.5 lb per day more than with shade only. The benefits to Jersey cows were slightly less.

Miller and Henning (58) observed marked breed differences in milk production among five dairy breeds in Puerto Rico (average temperature equal 84.6 F with 63.8 percent relative humidity) as well as seasonal differences. Erb and Shaw (1953) in a field study with 19 Holstein cows reported definite seasonal variations also. However the feed in neither of the two later examples was held constant. In Louisiana field studies, Branton *et al* (3) with 14 Holsteins and 15 Jerseys correlated outside temperatures (range of maximum temperature equal 65.5 to 95.0 F) and reported a 2.14-lb per day drop in milk (4 percent FCM) for each 1 F rise in body temperature. They reported that Holstein body temperatures ranged from 102 to 106.1 F on days of 90 to 95 F maximum temperatures. Corresponding Jersey temperatures ranged from 101.4 to 106.0 F.

Lee (54) recommended that protection be afforded milk cows in the Beltsville, Md., area when temperatures rose above 66 F in open fields and 71 F in open barns. Rusoff *et al* (75) in a well-designed experiment observed benefits of 0.8 to 5.5 lb per day extra milk with Holsteins from sprinkling plus shade as compared with shade alone during three summers in Louisiana. (Average maximum temperature for each two-month test period ranged from 86.4 to 92 F.) The benefits with Jerseys were slightly less. However, in Oklahoma, Nelson *et al* (61) found no advantage in an evaporatively cooled shelter as compared with an open-front barn.

Effect of Climate on Growth

There is very little information concerning the effect of climate on growth of dairy calves. Yet mortality among dairy calves is high, about 20 percent (Groth and Esmay, 25). Infectious agents are probably the primary cause, but the climate could well be a predisposing factor. The foregoing reference states that young calves are very susceptible to sudden temperature changes and cold drafts. However, Witzel and Heizer (95) reported that the only effect of cold weather on young calves in a Wisconsin loose-housing system where the barn temperatures occasionally dropped below 0 F was partially frozen ears. Fourt and Cleveland (23) also reported success with raising calves in an Idaho loose-housing system.

Warwick (90) quoted work at Missouri (Ragsdale *et al*, 1957) and the work of Hancock and Payne (1955) concerning the growth of calves at high temperatures, wherein initial exposures were made after one month of age. In the Missouri study an 80 F environment depressed the growth of Shorthorn calves by 0.5 lb per day over a one-year period. Similar dairy calf tests at Missouri (Johnson *et al*, 36) showed Holstein calves to gain about 0.2 lb per day more at 50 than at 80 F. Jersey calves also did slightly better at 50 than at 80 F. However, Brown Swiss calves did better at 80 than at 50 F. The study of Hancock and Payne showed poorer weight gains for one of each pair of several pair of monozygotic twin Jersey heifer calves that were raised in the hot climate of Fiji than were observed for the mates of each pair that were raised under identical conditions of feed and management in New Zealand.

Effect of Climate Upon Reproduction

One of the most common events ascribed to the effect of hot climates on domestic animals is a reduction of fertility (Lee, 53). Cattle are evidently no exception. Bonsma (2) reported seasonal fluctuations in both conceptions of cows and fertility of bulls among cattle in South Africa. Erb *et al* (19) reported that the Purdue University dairy herd had the lowest number of conceptions per service during the month of August. Schindler (76) reported that in the subtropical climate of Israel fertility is depressed beginning in June and continuing until October.

Schindler cited studies in Nebraska (Morgan and Davis, 59) (Schultze *et al*, 77), in Indiana (Erb *et al*, 1942), in Missouri Weeth and Herman, (92), and in Maryland Hilder *et al* (32) and Phillips *et al* (63) as showing the peak of fertility to occur in the spring and the minimum between June and September. Seath and Staple (78) reported that the lowest breeding efficiencies occurred in two Louisiana dairy herds during the summer months. Some of these authors express an opinion that high temperatures are a factor. Branton *et al* (4) report that the duration of heat periods were 5 to 6 hr shorter in Louisiana than in temperate regions.

Although there may be other possible causes, the effect of high temperatures on the quality and quantity of semen during various seasons apparently is receiving widest attention. Johnston and Branton (37) correlated decreased motility with increasing temperature. Johnston and Branton (38) also reported that the largest number of returns for breeding occurred during the peak temperature season in Louisiana. Casady *et al* (11) exposed four Guernsey bulls to high temperatures in a controlled-temperature environment. After exposure to 99 F motility was decreased and there were increased abnormalities. After exposure to 100 F one bull had no sperm in its ejaculates for two weeks. Another had no sperm for five weeks after exposure to only 86 F. It took about two months for these bulls to return to normal. The youngest bulls were most affected. In another controlled environment study (Kellgren, 43) with 2 Holstein, 1 Jersey, 2 Sindhi-Holstein, and 2 Sindhi-Jersey bulls, a temperature cycle of 75 to 95 F (vapor pressure equal 22 mm Hg) adversely affected the sperm of all bulls. It required five weeks for the sperm to return to normal. Naelapaa *et al* (60) in a similar study found that Sindhi crosses of Brown Swiss and of Holsteins were affected less than purebred Jersey and Holstein bulls. Patrick *et al* (62) reported that the semen of dairy bulls appeared normal when the bulls were housed in an 80 F environment.

Effect of Climate on Body Temperature

Rectal or other body temperature measurements are included in most environmental studies. Lee (53) states that the concentration upon body temperature as the criterion of heat tolerance assumes that the disturbance to other functions, including production, will be proportionate to disturbances of body temperature but that the time may come when this view may be modified. Rhoad (72) developed the Iberia heat tolerance test for cattle. It was based on rectal temperatures and the formula was as follows:

$$\text{Heat tolerance coefficient} = 100 - 10(BT - 101.0)$$

in which BT is the average of six rectal temperatures and 101.0 is a normal rectal temperature of a cow in degrees Fahrenheit.

Actually normal rectal temperatures vary over a wide range even within the zone of thermoneutrality. Dukes (17) gives the average temperature of a dairy cow as 101.5 F with a range of 100.4 to 102.8 F. Young dairy calf rectal temperatures average about 1 F above those of mature cattle. Brody (5) states that death usually follows when rectal temperatures exceed normal by about 8 F. However, milk production may decline when rectal temperatures rise as little as 1 F above normal.

Rectal-temperature measurements by Kibler *et al* (44, 46, 48, 49, 50 and 51) provided an excellent example of the response of Holstein, Jersey, and Brown Swiss cattle to prolonged exposures at several combinations of temperature, humidity, wind, and radiation. These tests showed that rectal temperatures respond rapidly to increasing environmental temperatures. (The lag ranged

from one to three hours.) The return to normal rectal temperatures with decreasing environmental temperatures was somewhat slower. In these tests rectal temperatures remained normal during two weeks of exposure at both 0 and 75 F constant air temperatures. However, with air temperatures above 75 F, they began increasing at an increasing rate — 102 F with an 80 F air temperature and about 108 F at 105 F air temperature (relative humidity ranging from 55 to 70 percent). The maximum duration of exposure at 105 F was 9 hr.

Most experimental data show that the rectal temperature of one animal may differ considerably from that of another at any given high-temperature stress condition even among animals of the same breed. The Missouri tests reported differences among animals within a breed of more than 2 F at air temperatures above 85 F, the size and level of production being the same — Kibler *et al*, (45).

Kibler *et al* (50) reported that high humidity accentuated the rise in rectal temperatures at air temperatures above 75 F. As much as a 2 F drop in rectal temperature was recorded when lowering the relative humidity from 81 to 60 percent at 95 F.

Kibler *et al* (51) reported benefit from fans. At 95 F and with lactating Holstein cows, the 10 mph air movement from the fans lowered rectal temperatures by about 2 F from those observed with 0.5-mph air movement.

Increasing the radiation from 5 to 180 Btu per sq ft per hr with a combination of incandescent and fluorescent lamps caused the rectal temperatures of three of six lactating Holstein cows in an 80 F environment to increase about 3 F, but those of the other three Holstein cows under identical treatment increased very little. Some radiation effect was observed with two of the six Holsteins when they were exposed to 70 F air temperatures — Kibler (51).

Although most of the foregoing rectal-temperature data were from one station, they are in reasonably good agreement with results that have been reported in numerous other references. With humidity a very important high-temperature consideration, many earlier references may be misleading, unless the relative humidity at which they were conducted is considered. Short-term exposures of less than one day have been studied by several investigators. Short-term exposure tests by McDowell, Fohrman, and Lee (55) were in reasonably good agreement with the long-term exposure tests of the Missouri laboratory.

Rectal-temperature measurements of calves at high temperatures and various humidities by Riek and Lee (74) indicated that calves could not withstand high air temperatures as well as mature cattle.

Effect of Environment on Skin and Hair Temperatures

Findlay (21) pointed out that little was known of the role of the animal's skin and hair in the dissipation of heat but that he regarded skin temperatures as an important measurement. Both hair and skin temperatures have been measured under various combinations of temperature and humidity at the Missouri laboratory — Thompson, Worstell, and Brody (84 and 85), Thompson, Yeck, Worstell, and Brody (87), and Stewart and Brody (81). Their results showed that skin temperatures increased from about 80 F at 5 F air temperatures to about 102 F at 100 F air temperatures. Thereafter, skin and rectal temperatures tend to parallel one another with rectal temperatures averaging about 2 F above skin temperatures. Hair temperatures, of course, are affected by length and density of coat as well as body and air temperatures. Generally, hair temperatures increased from about 50 F at 5 F air temperatures to about 101 F at 100 F air temperatures. Shortly thereafter they increased above skin temperatures and were practically coincident with room air temperatures.

Stewart and Brody (81) in measuring the reflectance of hair noted a decreasing absorption factor with rising temperatures and lighter color of hair among some animals with increasing temperatures.

Effect of Environment on Feed and Water Consumption

Winchester and Morris (93) prepared an excellent summary of research concerning the effect of environment on the water requirements of cattle. Generally water consumption for a given animal remains constant as air temperatures increase from 10 to 50 F but increases at an increasing rate as temperatures increase above 50 F. Water consumption very nearly doubles as temperatures increase from 80 to 95 F. The exact quantities of water consumed vary tremendously with individuals. Thompson, Worstell, and Brody (82) cite water consumption rates of three Jersey cows of similar size, stage of lactation, and under identical environmental conditions (95 F) and management of 40, 25, and 14 gal per day, respectively. Similar differences among these three animals were apparent at air temperatures of 85, 90, 100 and 105 F.

The moisture content of feed, body weight, level of milk production, butterfat composition of milk, and stage of gestation were expressed as affecting water consumption in the Winchester and Morris summary. Their summary presents a table that might well be used to draft a curve of water consumption versus environment.

Feed consumption has been studied under various environmental conditions both in field and in laboratory studies. The laboratory at the University of Missouri provided controlled conditions of temperature and humidity with exposures at each condition that were of sufficient duration to provide good data concerning the effects of environment on feed consumption. A summary of the first few years of tests in this laboratory was prepared by Worstell and Brody (96). Decreasing environmental temperatures from 40 to 8 F were associated with increased feed (TDN) consumption of 26 percent in Jerseys and 8 percent in Holsteins. This represented a decreasing efficiency of milk production relative to feed consumption, as there was a normal decline in lactation as the temperatures were lowered. Some compensation for lowered milk production was realized through some body weight gain during this period. As the temperatures increased above 50 F, there was little change in TDN consumption until rectal temperatures began increasing. When rectal temperatures began increasing, feed consumption, as did milk production, dropped off sharply.

Other results from the Missouri laboratory — Ragsdale, Thompson, Worstell, and Brody (70), Brody, Ragsdale, Thompson, and Worstell (7) — showed that humidity, wind, and radiation affected feed consumption much as they affected milk production during tests that caused rectal temperatures to rise. Their data generally show milk production to begin declining slightly sooner and at a sharper rate than feed consumption at the onset of high temperatures.

Effect of Environment on Other Physiological Reactions

The significance of other physiological measurements, such as respiration rate, pulse rate, pulmonary ventilation rate, blood pressure, electrocardiograms, thyroid activity, blood composition, urine composition and volume, and activity of cattle are discussed by Brody (5) and Findlay (21). None of these are presently being considered as a better index of animal comfort than rectal temperature. They are primarily of value to the physiologist for purposes of evaluating the mechanisms of homeothermy or as indexes of heat tolerance. A paper by McDowell, Lee, and Fohrman (56) provides an insight into background considerations for the use of respiratory activity as an index of heat tolerance. They concluded that respiratory volume was a more sensitive index of heat tolerance than respiratory rate.

Mechanisms and Magnitude of Heat Dissipation

Thompson, McCroskey, and Brody (83) presented data showing the percentage of total heat production that was lost by the vaporization of all water from the cow's body (the respiratory tract plus the outer body surface). At 0 F only about 8 percent of the total heat production was dissipated through vaporization of water. This percentage increased gradually up to 20 percent at 50 F and thereafter rose rapidly to about 100 percent at 100 F. Kibler and Brody (46) presented data showing partitioning of evaporative cooling between outer body surfaces and the respiratory tract. The respiratory surfaces accounted for about 5 percent of total heat production at 5 F with the percentage increasing up to about 20 percent at 90 F and thence up to 25 percent at 95 F. The outer body surfaces accounted for the major portion of evaporative cooling among the Holstein and Jersey cows.

The foregoing tests were conducted under circumstances where the room-surface temperatures equalled the air temperatures. There are conflicting opinions in regard to the method by which vaporization occurs. However, Findlay (22) and his associates, Goodall and Yang, determined that cattle have sweat glands which are active. The degree to which they function remains a question and the consideration of vaporization from the skin of cattle as a diffusion process retains favor among some physiologists.

Although heat loss by radiation is considered as occurring among cattle, no evidence of the experimental evaluation of its relative role in heat dissipation was found in literature.

Heat production literature may be divided into that which pertains to heat production of individual animals as measured through measurements of oxygen consumption and into heat dissipation from groups of animals and their environment as determined through ventilation exchange measurements. The results of tests concerning the latter in the Climatic Laboratory at the Missouri Agricultural Experiment Station by Thompson (86, 88) showed that total heat production (Btu per 1000 lb of body weight per hour) decreased with increasing temperature from about 3800 at 10 F to about 3000 at 80 F and dropped off more rapidly thereafter to slightly less than 2500 at 95 F. The latent heat portion of this heat load, however, increased with increasing temperature from about 600 (Btu per 1000 lb of body weight per hour) at 10 F to about 1300 at 65 F and thence more rapidly, increasing to about 2400 at 90 F. Increasing stable relative humidity from 40 to 90 percent slightly increased total stable-heat dissipation but slightly decreased the latent heat portion of the total. Increasing the air velocities over the cows from 0.5 to 10 mph increased total heat loads at temperatures below 65 F (by about 25 percent at 20 F) but had no effect above 65 F. The latent heat portion of the load was changed only slightly with the increased air velocities.

Metabolic heat production and measurements with individual animals receiving full feed and under various constant-temperature conditions were reported by Kibler and Brody (45, 46 and 48). Their data show trends similar to those of the foregoing stable-heat dissipation tests, decreasing at a rate of about 8 Btu per 1000 lb body weight per hour for every 1 F rise in air temperature between 10 and 80 F. Worstell and Brody (96) pointed out that the metabolic rates began to drop more sharply with increasing temperature when rectal temperatures of these cattle rose. A correlation by Yeck and Stewart (97) of metabolic heat production and total stable dissipation among the cows tested showed that metabolic heat production accounted for about 75 percent of the total stable heat dissipation.

Evaporative heat loss measurements with individual animals among the laboratory group from which the stable latent heat loads were obtained were also summarized by Yeck and Stewart (97). Their summary indicated that slightly more than 50 percent of the stable moisture load was vaporized directly from the animal's body.

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Effects of Climate and Environment on Beef Cattle

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THIS review of literature published in recent years deals with certain environmental and climatic effects on performance and physiological responses of beef cattle. The emphasis is on hot weather climatic effects because these seem to have been of more concern than cold weather climatic effects. It seemed desirable to classify this review according to the general headings of *(a)* ambient temperature effects, *(b)* radiation effects, *(c)* humidity effects, and *(d)* shelter and management effects.

Report prepared for the special use of the Technical Advisory Committee on Plant and Animal Husbandry jointly sponsored by the American Society of Agricultural Engineers and the American Society of Heating and Air Conditioning Engineers, March 1958 (revised December 1958).

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Ambient Temperature Effects

Body Temperature. Findlay (4)* cited the data, Table I, from others on the body temperatures of Angus and Hereford cattle at air temperatures from 50 to 100 F.

*Numbers in parentheses refer to appended references.

TABLE I

Air Temperature, F	Body Temperature, F Angus	Hereford
50	101.0	101.0
81	102.9	102.2
84	103.0	102.8
90	104.2	102.8
100	106.2	103.4

Ragsdale, *et al* (18) found that the average rectal temperature of calves reared at 50 and 80 F, respectively, differed by about 0.4 deg for Brahman cattle, 0.3 deg for Santa Gertrudis and 2.1 deg for Shorthorns, with the higher values prevailing at 80 F.

Findlay (4, p. 22) gave results on the effect of air temperature on rectal temperatures of Aberdeen Angus cattle, Brahman, and Aberdeen Angus-Brahman crosses. When the atmospheric temperature was above 50 F and under exposure to solar radiation, there was a significant and general increase in the rectal temperature with air temperature within each of the breeds or crosses. The Brahman cattle maintained body temperatures at a more uniform level, and the Aberdeen Angus at a less uniform level than the crosses.

Age of animal seemed to affect response to high environmental temperatures. Findlay (4, p. 29) concluded that calves could not withstand as high air temperatures as cows.

Experiments on the effect of high environmental temperatures on body temperatures of approximately 366 beef cattle at McGregor, Texas, have been reported by Cartwright (3). A chamber large enough for several pens was maintained at a temperature of about 105 F plus or minus 2 deg. The cattle were Herefords, Brahmans, Santa Gertrudis, some crosses of Herefords with Brahmans, and a few Red Polls. They were maintained for eight-hour periods in the chamber at 105 F. Body temperatures of the cattle in the chamber were correlated with chamber respiration rate with a correlation coefficient of 0.52 over all and 0.29 within breeds or sexes. Both of these coefficients were significant at the 0.01 probability level. Also body temperatures of the cattle as measured in the heated chamber were correlated with summer gain with negative correlation coefficients (both significant) of 0.22 over all and 0.17 within breeds or sexes. Body temperature in the heated chamber was significantly affected by differences in age, sex, and breed or cross.

Surface Temperature. Stewart and Shanklin (19-b) measured changes in skin and hair surface temperatures of Shorthorn, Brahman, and Santa Gertrudis cattle raised for 13½ months at constant air temperatures of 50 and 80 F. Skin temperatures decreased and hair temperatures increased as body weight increased for Brahman and Santa Gertrudis cattle raised at 80 F. However, main body skin and hair temperatures both decreased with increasing weight for all breeds raised at 50 F. The constant-temperature periods of growth were found to have no effect on subsequent response to other environment temperatures, as regards skin and hair temperatures.

Pulse Rate. Findlay (4) concluded that an increase in atmospheric temperature caused a decrease in the pulse rate of cattle. This is the reverse of the effect that occurs with man. However, there is a critical temperature or heat load at which the downward trend is reversed. Normal pulse rate of cattle is thought to be about 60 to 70 beats per minute but is influenced by individual differences and by age. Young cattle have rates of about 70 to 90 beats per minute. Cartwright (3) found that at an environmental temperature of 105 F pulse rate depended on sex and breed.

Respiration Rate. Marked differences exist in the effects on respiration rate of ambient temperature because of differences in breeds, according to Findlay (4, p. 38-39). Above 80 F predominantly Aberdeen Angus cattle sharply increased their respiration rate to 110 counts per minute or more at temperatures of 99 to 102 F. Pure Aberdeen Angus had respiration rates of above 150 counts per minute. Cattle which had one-half or more Brahman blood maintained more uniform respiration rates with a maximum of about 60 for half-and-half Brahman and Angus, and about 45 for pure Brahmans. Respiration rate was significantly affected by differences in breed and sex — Cartwright (3). Vernon *et al* (24) found that a highly significant correlation existed between respiration rates and rectal temperatures for cattle including Brahmans, Afrikander-Angus crosses, Brahman-Angus crosses, and Aberdeen-Angus yearling, 2-year old, and 3-year old and older cows. Values of r were significant and ranged from 0.5 to 0.6 for all but the mature Brahman cows. No significant correlation existed between respiration rates and production as measured by weight at birth, at 6 months and 5 years of age, either of a beef cow or her progeny of these same ages.

Kibler and Brody (11) found that the mean respiration rates were higher at an 80 F environment than at 50 F by 9.8 counts per minute in Brahman heifers, 19.1 for Santa Gertrudis, and 43.7 for Shorthorns. The mean respiration rates at 80 F were 31.9 for Brahmans, 47.6 for Santa Gertrudis, and 98.1 for Shorthorns. These measurements extended over an eight-month period on individuals kept in the climatic laboratory at Missouri.

Moisture Production and Transpiration. Experiments by Yeck (25) with Santa Gertrudis, Brahman and Shorthorn calves in a climatic chamber at 50 F and 80 F, respectively, indicated that stable moisture production increased rapidly day by day during the first three months. Stable moisture production at 50 F was only about 50 to 60 percent of that at 80 F environmental temperature. Stable moisture was moisture dissipated by the animals, their bedded area, and watering devices. Stable-moisture production rate increased about 20 percent during the one-week interval between cleaning at 80 F, whereas at 50 F, stable moisture production rate increased only about 11 percent. At 25 weeks of age, moisture dissipation from the bedded area was 0.75 lb per hr per 1,000 lb of body weight at 50 F; and 0.83 lb per hr per 1,000 lb of body weight at 80 F. At 65 weeks of age, these values were 0.36 and 0.41 lb per hr per 1,000 lb of body weight, respectively, at 50 and 80 F.

According to McDowell (15), based on findings at the Missouri climatic laboratory, Shorthorn heifers had higher surface evaporation rates than either Santa Gertrudis or Brahman heifers. However, surface evaporation by Brahman cattle continued to rise with increased air temperature. Shorthorn cattle exhibited little or no change in transpiration above 80 F. Findlay (4, pp. 83-84) from data by Rhoad, found that the amount of water transpired through skin on the back and side surfaces of predominantly Aberdeen-Angus cattle increased about nine-fold when air temperature increased from about 55 to 90 F. For cattle with one-half or more Brahman blood, the increase was about five-fold.

Growth. Results from growth experiments in the Missouri climatic laboratory with Santa Gertrudis, Shorthorn, and Brahman cattle have been reported by Ragsdale *et al* (18). Growth data were fitted to an exponential growth curve of the form $W = A - Be^{-Kt}$ where W is body weight in pounds at age t in months. The constants obtained are listed in Table 2.

TABLE 2. GENETIC GROWTH CONSTANTS

Temperature of environment	Breed	Predicted mature weight (A) lb	B (lb)	K
80 F	Santa Gertrudis	1500	1520	0.053
	Shorthorn	1300	1400	0.045
	Brahman	1300	1270	0.058
50 F	Santa Gertrudis	1500	1590	0.064
	Shorthorn	1500	1570	0.052
	Brahman	1300	1270	0.053
Open shed	Santa Gertrudis	1500	1550	0.054
	Shorthorn	1500	1575	0.046
	Brahman	1300	1445	0.060

Brahman and Santa Gertrudis cattle grew well at the 80 F environmental temperature. The less tolerant Shorthorns made relatively poor growth gains at 80 F. At sixteen months of age, the Shorthorns were about 200 lb lighter in body weight than the other breeds. The Brahmans did not do quite as well at 50 F as at 80 F. In a companion experiment with these same breeds in an open shed, all breeds made normal growths.

O'Bannon *et al* (17) found that Brahman heifers grew more rapidly under a constant environmental temperature of 80 F than at 50 F. Santa Gertrudis grew equally well at 50 F and 80 F. Breed differences in growth rate were closely associated with breed differences in structural peculiarities that gave the more tolerant breeds a larger surface area per unit weight and larger vascularity of some organs. Shorthorn cattle grew 40 to 50 percent more rapidly at 50 F than at 80 F.

Feed and Energy Use. Kibler *et al* (12) made comparisons of the energy metabolism and the TDN consumption for ages of 3 to 15 months for Brahmans, Santa Gertrudis and Shorthorn heifers at constant temperatures of 50 and 80 F. At both of these temperatures, the energy cost in calories per pound of gain was lowest in the Brahmans and highest in the Shorthorns. For all

breeds, the energy cost per pound of gain was less at 50 F than at 80 F. The mean energy metabolism over a one-year period in units of calories per pound of gain was 5,340 for the Brahmans, 5,550 for the Santa Gertrudis and 5,590 for the Shorthorns at a 50 F environmental temperature. At the 80 F environmental temperature, the comparable figures were 5,490, 5,570, and 6,180, respectively. In the same order, the pounds of total digestible nutrient per pound of gain were 5.00, 4.60, 4.88 at 50 F. At the 80 F environmental temperature, these figures were 5.03, 5.55, and 5.37, respectively.

Hair Coat Characteristics. According to McDowell (15), based on findings by Yeates in Brisbane, woolly-coated cattle are at a disadvantage in hot weather. A curly coat constitutes a definite threat to the animal's life at 105 F. Cattle with short, smooth coats seem to have superior heat tolerance.

Bonsma (2) presented data emphasizing the importance of a short sleek hair coat in heat tolerance of cattle. For cattle, including Afrikanders, woolly-coated Afrikanders, Herefords, and Nguni, the mean regression of body temperature on environmental temperature was $Y=98.75+0.04298X$, where Y is body temperature in the sun and X is environment temperature, all in degrees F. For the same animals, but in the shade, the regression relationship was $Y=101.41+0.00731X$. However, considering hair coat characteristics, the mean body temperature for the woolly-coated Afrikanders was nearly 105 F, compared to only 102 F under the same conditions for smooth-coated Afrikanders. The woolly coated Afrikanders had low heat tolerance. Several died from heat stroke when they were moved between pens on a hot day.

According to O'Bannon *et al* (17), Brahman and Santa Gertrudis had short sleek reflective hair that did not interfere with heat dissipation from the surface, but the Shorthorns had heavy, woolly, dull hair. Close clipping of Shorthorn hair coats caused a drop of 1.5 and 0.6 F at 6 and 9 months of age, respectively, in rectal temperatures in the 80 F chamber.

Heat Production. Results by Yeck (25) with Brahman, Santa Gertrudis, and Shorthorn calves ranging in age at the beginning of the experiment from one to three months and continuing for 13½ months in 50 F and 80 F climatic test chambers indicated that, at both temperatures, stable heat production increased rapidly from day to day during the first three months. Increases were much less during the remainder of the test period. Stable heat was defined as the heat dissipated by the animals and the bedded area. It was found that heat dissipation was nearly the same at 50 and 80 F. Latent heat was from 35 to 39 percent of the total heat at 50 F and 67 to 71 percent of the total at 80 F. Buildup of litter during intervals between weekly cleaning of the pens increased stable heat production from about 1100 Btu per hour-calf immediately following cleaning of pens to about 1300 Btu per hour per calf at the end of the one-week period between cleanings. These results were for the 80 F test room. For the 50 F test room, the increase in stable heat production due to litter accumulation was from 1000 Btu per hour per calf immediately following cleaning of the pens to slightly under 1100 Btu per hour per calf at the end of the one-week period. Animal heat production was about 92 to 97 percent of the stable heat. For practical purposes, animal heat production of a given breed could be increased by 5 percent to predict stable heat. Stable heat dissipation per unit body weight should be fairly constant between 10 and 20 weeks of age. For Shorthorn calves, Brahmans, and Santa Gertrudis during this period, stable heat dissipation was estimated to be 5,100, 3,800, and 4,400 Btu per hour for each one thousand pounds of body weight. These values would be appropriate for either 50 or 80 F temperatures. Stable heat per unit body weight reached a fixed value at 60 weeks of age. Higher stable temperatures increased litter production and bedding requirements for beef calves. At 50 F, between ages of 10 to 65 weeks, bedding requirements increased from about 30 pounds per week to about 100 pounds per calf per week. At 80 F, requirements increased from 35 pounds per calf per week to about 150 pounds per calf per week. Increased water consumption at 80 F was considered to be the important factor in the increased bedding requirements.

Radiation Effects

Surface Temperature. Kelly *et al* (10) measured temperatures on the slick hair of cattle in the sun. Hair temperatures were 105 F, compared to 119 to 124 for comparable conditions but measured on curly-haired areas. Data compiled by Kelly in the *Agricultural Engineers Yearbook* (8, p. 114), for average surface temperatures for animals in the sun and in the shade, respectively, when air temperatures are 100 F are given in Table 3.

TABLE 3

Location on animal	Average surface temperature Animal in sun	Animal in shade
Back	125 F	103 F
Side (away from sun)	114 F	105 F
Side (towards sun)	131 F	---
Belly	109 F	---

Hair Coat Characteristics. Data from Riemerschmid and Elder cited by Findlay (4, pp. 71-72), for the solar absorptivity of hides of different breeds of cattle were: White Zulu, 49 percent; cream Simmen-Thaler, 50 percent; red Afrikander, 78 percent; dark red Sussex, 83 percent; black Aberdeen-Angus, 89 percent. The solar radiation absorptivity by the coats of cattle varied from above 93 percent at incidence angle of 0 deg to about 76 percent at an incidence angle of about 73 deg. Other data by Rhoad cited by Findlay (4, pp. 23-24), showed that clipping the hair from an Angus increased the animal's discomfort when exposed to the sun. Nelson and others (16) used an adaptation of the sol-air thermometer to measure solar radiation absorption and surface convective effects as influenced by nature of hair coat. It was found that for black and red cattle surfaces the b/f_{cro} ratio decreased from about 0.24 in still air to about 0.18 at a wind speed of 800 fpm. For white surfaces, as on a Hereford, this factor decreased from about 0.20 in still air to about 0.14 at 800 fpm. Here, b is the solar absorptivity of the hair or hide surface and f_{cro} is a combined convective and radiation surface coefficient of heat transfer.

Stewart (19-a) made spectrophotometer analyses of cattle hair samples to measure reflecting power in the spectrum of 290 to 1200 millimicrons. This spectrum includes approximately 83 percent of the solar energy reaching the earth. For Shorthorn cattle, the solar absorption coefficients were found to be: for roan color, 0.672; for dark red, 0.778. For Hereford cattle the solar absorption coefficients were found to be: for the light tan, 0.645; for medium red, 0.760; and for very dark red, 0.819.

Behavior Effects. According to Findlay (4, chap. 2), from data by Rhoad and Bonsma, grazing during periods of high solar radiation intensity was related to the amount of tropical blood present in cattle. Striking differences occurred between tropical and temperate breeds. Brahmans spent about 19 percent of the time resting in the sun and never sought shade. During days with sun but no wind, pure Aberdeen-Angus spent about 54 percent of the time grazing and the rest of the time in shade. Pure Brahmans grazed 71 percent of the time but when resting remained in the sun.

Radiation Heat Load. Kelly *et al* (10) calculated heat exchange by radiation between cattle bodies and surroundings for cows weighing 750 lb when air temperature was 100 F and wind velocity was under 1 mph. For an unshaded cow, heat gain to the cow in Btu per hour was 246 for the back surface, 10 for the sides, and 63 for the belly. For the shaded cow, heat loss from the animal surface in Btu per hour was 2 Btu per hour for the back, 12 for the sides and 2 for the belly. When the convective heat transfer was taken into account, the combined radiation and convective exchanges were: for the unshaded cow, a gain of 567 Btu per hour; for the shaded cow, a loss of 777 Btu per hour. A film conductance coefficient of 2.6 was used for these calculations.

Humidity Effects

Body Temperatures. According to Findlay (4, p. 23) based on data from Rhoad, body temperatures for Aberdeen-Angus and Brahman crosses as well as pure Brahmans tended to decrease or remain constant as humidity decreased from about 60 percent relative humidity down to 50 percent, even though ambient temperatures rose from 93 to 95 F. Body temperatures for pure Aberdeen-Angus did not decrease with decreasing relative humidity in this temperature range. Findlay concluded (p. 29) that although calves are not able to withstand as high air temperatures as cows, humidity has much less effect on the body temperature of calves than on that of cows.

Respiration Rate. Cartwright (3) in experiments with calves in a hot climate chamber found that relative humidity was significantly correlated with chamber respiration rate, correlation coefficients of 0.48

(over-all), and 0.34 (within breeds or crosses and sex). These experiments were conducted with Herefords, Brahmans, and Santa Gertrudis, with crosses among these breeds and a few Red Polls.

Shelter and Management Effects

Shade. McDaniel *et al* (14) experimented with effects of type of shade on performance and grazing habits of Hereford and Aberdeen-Angus cows and calves over a 4-year period. The shade treatments were in pasture in cutover pine stands at the West Louisiana Experiment Station. Approximately 100 head per year of registered and grade Hereford and Angus cows with calves were used. Test periods averaged 25 days. Shade treatments included (1) abundant natural shade including gum, oak, and bay trees, (2) scanty natural shade, and (3) artificial shade consisting of 12 x 24-ft structures 7 ft high with roofs of hay, straw or pasture clippings. Shades provided about 32 sq ft of space per animal. Cows on pasture with either abundant or scanty natural shade made significantly greater gains than cows grazing pastures without shade. Calves grazing pastures with abundant or scanty natural shade, or artificial shade, made significantly greater gains than calves grazing without shade. Maximum differences between animals with abundant shade versus no shade was 1.24 lb per day gain for the cows and 0.67 lb per day for the calves. Artificial shade compared to no shade produced extra gain of 0.89 lb per day for the cows and 0.60 lb per day for the calves. The low height and small per head space allowance of the artificial shade was thought to contribute to the relatively poor performance of cattle under artificial shade.

In experiments at the range cattle mineral station, Wilburton, Okla., Totusek *et al* (20, 21, 22 and 23) found in experiments extending over a 4-year period beginning with 60 two-year-old grade Hereford heifers on native grass pasture that, in general, weights of cows and calves were not greatly affected by shade. Cows and calves without shade consistently had higher respiration rates than cattle under the shade. The weight gain of cows during the 1954 summer averaged 46 lb average per cow with shade and 69 lb without shade. There was some indication that, although the cows tended to gain more weight on pasture with shade, calves without shade had an average weaning weight significantly greater than calves with access to shade. It was suggested that calves without shade spent more time grazing, but calves with shade spent less time grazing.

McCormick *et al* (13), in experiments with steers grazing coastal Bermuda grass in Georgia, found that the average gain rate of eighteen steers in the period May 16 to September 18 was 1.27 lb per day when straw and aluminum shades were provided at a rate of about 40 sq ft area per head. Average gain rate for nine steers not having access to the shade was 1.45 lb per day. During the period August 14 to November 6, eight steers fattened in dry lot with access to aluminum shade was 2.58 lb per day; but without shade the gain was 2.60 lb per day. Steers fattened on pasture with access to aluminum shade gained 2.18 lb per day. Without shade the gain rate was 2.09 lb per day.

Surface temperatures of Hereford cattle in the sun and shade were measured by Kelly *et al* (10) using the touch thermocouples and Hardy radiometers. During air temperatures of 100 F, temperatures on the back were 119 to 133 F; on the side of the animal away from the sun, 114 F, and on the side facing the sun 131 F. Temperatures on the belly were 109 F. Surface temperatures for an animal in the shade were 101 to 105 F on the back, and on the side away from the sun 101 to 107 F. Very little air movement occurred during these measurements.

Fanning and Ventilation. Bond *et al* (1) studied the effects of fanning or forced circulation using large fans. Hereford calves weighing from 554 to 621 lb were subjected to 400 fpm air circulation under a shade in the Imperial Valley of California. Another group was held in a naturally ventilated pen with a mean air speed of about 20 fpm. The rectal temperatures of fanned animals did not increase during the observation period although air temperatures increased about 6 F. The unfanned animals experienced a rise in rectal temperatures of about 1.4 F, from 104.1 to 105.5 F. Surface temperatures of both sets of calves increased with increasing air temperature but for the unfanned calves averaged about 2.5 F higher throughout the day. In feeding and performance trials, Bond *et al* (1) found that fanning with a 42-in. fan nominally rated at 17,000 cfm and providing an average breeze of 3.7 mph over a 70-day period produced additional daily gain of 1.03 lb in 1955 and 0.53 lb in 1956 as compared with animals in a normal or natural breeze averaging 0.6 mph. The fanned cattle used 406 lb less feed per 100 lb gain during the 1955 tests and 183 lb less in 1956, compared to the unfanned cattle. During most of the test period, the fan operated continuously. According to Ittner and others (7), average daily gain for unfanned animals was 1.29 lb per day. Feed utilization was 1,330 lb for each 100 lb of gain. The fanning treatment produced a gain of 2.32 lb per day at 924 lb of feed per 100 lb of gain. In subsequent experiments, the differences were not as great. Unfanned animals gained 1.87 lb per head per day. The fanned group gained 2.40 lb per day. The feed intake of the animals in the fanned pens was higher than the others during both years. Average air velocities at the center of the pen in 1955 were 55 fpm in the unfanned pen and 325 fpm in the fanned pen. The animals in the unfanned pen had body temperatures as much as 1.35 F higher and skin temperatures as much as 5.8 F higher compared to animals in the fanned pen.

Cooled Drinking Water. Kelly *et al* (9) found that cooling the drinking water of Hereford cattle to a temperature of 65 F during hot weather in the Imperial Valley of California produced uniformly higher weight gains than prevailed for cattle with uncooled drinking water. The increase in daily gain amounted to 0.32 lb per animal. In one experiment, evaporatively cooled water was used at a temperature of 75.4 F, but did not produce a significant effect on growth. It was thought that some physiological effect other than reduced heat load explained the increased gains since the cooling effect on the cattle due to the cooled drinking water was only about 4 percent of the daily heat production of the animals.

Evaporative Cooling of Shelters. Kelly *et al* (9) tested spraying and fogging of cattle in the Imperial Valley of California. A fine misty spray did not seem beneficial. A coarser spray that caused wetting of the animals to the skin was relatively effective. The wetted animals usually had body temperatures 2 to 3 deg lower than dry animals and respiration rates about 20 counts per minute less. In later tests with a single coarse spray in a stall between shade and pasture, the sprayed cattle averaged 0.37 lb per day gain more than unsprayed cattle.

The following year the sprayed cattle averaged 0.22 lb per day greater gain. A fine, mist spray in a shade shelter increased daily gain only 0.06 lb per day. This was not significant. It was observed that the hair was seldom wetted to the skin on the animals. In 1952, sprayed animals under shade gained 0.10 lbs per animal per day less than unsprayed animals. In other tests, 2500-cfm evaporative coolers maintained maximum outdoor minus indoor temperatures of 10 F and less. Brahman and Hereford crosses showed no significant differences in gains as influenced by the cooled versus uncooled shade. Herefords gained 1.05 lb per day under the cooled shade and 0.69 lb per day under an uncooled galvanized steel shade. Kelly *et al* (10) found that cattle must learn the value of a spray before it becomes effective in improving comfort. They seemed to prefer a coarse spray to a fine, mist-type spray. Use of sprays or showers was generally confined to late morning and most of the afternoon.

Surround Characteristics. Results reported by Ittner *et al* (5) revealed that wire enclosed corral pens produced a cooler environment by about 3.8 F than corrals surrounded by heavy wooden fence. Wind velocity was 1.32 mph greater in the wire pen and water temperatures were 4.9 F lower, compared to the wooden fenced pen. Cattle kept in the wire-enclosed pen gained 1.94 lb per day while those in the wooden fenced pen gained 1.51 lb. Feed per 100 lb gain was 1,085 lb for steers in the wooden pens and 867 lb for steers in wire pens.

Feed Consumption. Ittner *et al* (6) studied cattle performance of Hereford cattle in the irrigated desert of California. Their results on performance of Hereford cattle under these conditions are given in Table 4.

TABLE 4. HEAT INCREMENTS, FOOD INTAKE, NET ENERGY AND GAIN IN WEIGHT FOR STEERS IN A HOT CLIMATE

Number of animals dates, average weight, daily gains	Ration per head, lb	Dry matter eaten, lb	TDN eaten, lb	Metabolizable energy eaten, lb	Heat increment of ration, million calories	Net energy intake per day, million calories	Net energy for maintenance, million calories	Net energy available for production, million calories
Hereford steers (4) Aug 8 - Sep 5, 1950 Av wt, 910 lb Daily gain, 0.86 lb	Roughage 23.64 Concentrates 0	21.4	12.10	19.4	11.3	8.1	6.4	1.7
Hereford Steers (8) Aug 7 - Sep 3, 1951 Av Wt, 1,046 lb Daily gain, 1.73 lb	Roughage 12.25 Concentrates 9.70	19.9	13.6	23.1	10.5	12.6	7.1	5.5
Hereford steers (10) Jul 2 - Sep 11, 1952 Av Wt, 795 lb Daily gain, 0.78 lb	Roughage 19.36 Concentrates 0	17.4	10.1	16.2	9.2	6.0	5.8	1.2
Hereford steers (12) Jul 2 - Sep 10, 1952 Av wt, 804 lb Daily gain, 2.42 lb	Roughage 13.97 Concentrates 8.60	20.4	13.6	22.9	10.8	12.1	5.8	6.3

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Environmental Studies with Swine

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INVESTIGATIONS of the relationship between swine and their environment are generally either of a basic nature to determine the effect of environment upon the physiological responses and growth of swine, or they are application studies designed to determine methods of improving the environment for protecting hogs from adverse environmental conditions. Both phases of investigations are essential in order to achieve the ultimate objective of minimizing environmental stress at an economical animal production level.

It is perhaps best to consider a summary of such investigations in terms of three growth cycles: *(a)* sows, *(b)* baby pigs from farrowing to weaning, and *(c)* fattening hogs from weaning to market, because of differences in importance of the various environmental influences in each case.

Sows

There have been only a few investigations concerning the effect of environment on gestating and lactating sows. However, there is a recent increase of interest in this problem, and undoubtedly greater emphasis will be placed on the environment of the sow, particularly during the latter weeks of gestation and during the first days after farrowing.

In tests designed to study the effect of high air temperatures on pregnant sows, Heitman, Hughes, and Kelly (1)* showed

Report prepared for the special use of the Technical Advisory Committee on Plant and Animal Husbandry jointly sponsored by the American Society of Agricultural Engineers and the American Society of Heating and Air Conditioning Engineers, March 1958 (revised December 1958).

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*Numbers in parentheses refer to the appended references.

that continuous exposure to high temperatures averaging 99 F for periods of about 8 days produced pronounced evidence of physical discomfort, but no abnormalities occurred with regard to litter size or health of 13 sows subjected to such exposure during their 13th to 15th week of gestation. One aborted from other causes and one died from heat prostration, the rest successfully farrowed. All sows lost weight, some losing an average of 5 lb per day.

An open sow, along with a pregnant animal, was subjected to increased ambient temperatures. The open sow showed a minimum respiratory rate of 64 per minute when the air temperature was 98 F, whereas the respiratory response of the pregnant sow went as high as 186. Even though the open sow lost 33 lb during an 8-day test, results indicated she was not as stressed by the high temperatures as the pregnant sow. It appeared that the pregnant animal had difficulty dissipating the heat caused by the additional "metabolic load."

Bond, Kelly, and Heitman (2) measured the heat and moisture lost from sows and their litters immediately before farrowing and through an eight-week period of weaning (Fig. 1). There was no apparent effect of environment on the heat loss of the sows and litters raised in constant temperature environments of 60, 70, and 80 F. During the eight weeks after farrowing, the sows in the 60 and 70 F environments gained 2 and 30 lb, respectively, whereas the sow in the 80 F environment lost 90 lb. However, the latter sow raised the largest litter both as to number and weight per pig. These tests indicated a probable need for two separate environments in the farrowing house, one for the sow at 60 to 70 F and one for the litter at about 80 F.

TABLE 1. REPRODUCTIVE PERFORMANCE OF SOWS THAT HAD ACCESS TO SHADES WITH AND WITHOUT WATER SPRINKLERS DURING PREGNANCY, SUMMER, 1956

Treatment of Bred Sows	Sprinklers	No sprinklers	Difference
Number of sows	17	17	
Farrowing data:			
Total pigs farrowed per litter	10.88	9.24	1.64
Live pigs farrowed per litter	10.06	7.71	2.35*
Stillborn pigs per litter	0.82	1.53	—0.71
Decomposed embryos per litter	0.06	0.65	—0.59
Litter birth weight (total pigs), lb	27.90	24.90	3.00
Litter birth weight (live pigs), lb	26.20	21.20	5.00
Weaning Data:			
Pigs weaned per litter	7.76	5.71	2.05†
Litter 56-day weight, lb	306.76	221.35	85.41†

*P is less than 0.05. †P is less than 0.01.

TABLE 2. AIR TEMPERATURES UNDER SHADES AND AVERAGE RECTAL TEMPERATURES OF EIGHT SOWS WITH ACCESS TO SPRINKLERS AND A LIKE NUMBER WITH NO SPRINKLERS (5)

	Air temperatures, F		Rectal temperatures, F	
	Sprinklers	No sprinklers	Sprinklers	No sprinklers
July 24	96.0	96.0	101.2	102.7
31	100.0	100.0	101.1	104.2
August 7	101.5	104.0	101.1	103.9
14	104.5	108.5	100.7	104.6

Andrews (3) indicates that field observations of sows farrowing in July and August warrant the conclusion that sows are subject to heat stress and heat prostration and suggests that some cases of lactation failure may be related to high ambient temperatures. According to Andrews, "The continuous farrowing of swine, especially in southern areas, will justify some type of cooling for the sows."

F. N. Stewart (4), a hog producer of Randolph County, Ga., air-conditioned a farrowing barn with the result that he got "two extra pigs per litter." He observed: "There is less crushing of pigs when sows are comfortable; they don't get up and down so often to drink or root up fresh bedding."

In Oklahoma tests Whatley *et al* (5) found that 17 sows and gilts sprinkled with water during pregnancy farrowed an average of 2.35 more live pigs per litter than a similar unsprinkled group (Table 1). One 12 x 24-ft galvanized steel shade 6 ft high was

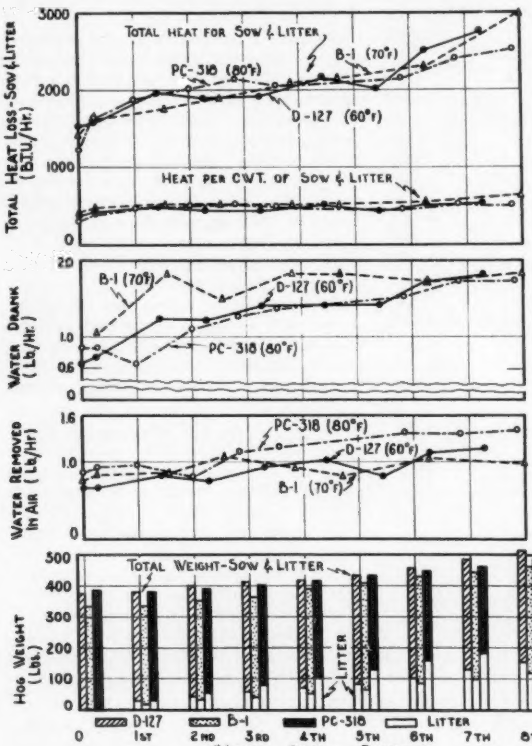

Fig. 1 Heat and moisture loss and water consumed by sows and their litters from farrowing to weaning eight weeks later. Water removed is the moisture removed by the air ventilating the test chamber. Bond *et al* (2)

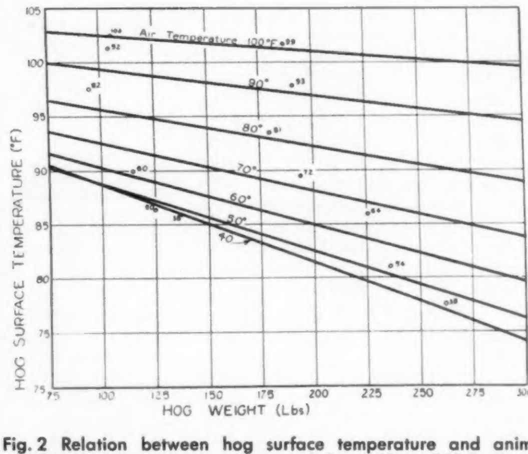

Fig. 2 Relation between hog surface temperature and animal weight, at air temperatures ranging from 40 to 100 F. Actual observations at indicated air temperatures also shown to illustrate goodness of fit. Kelly *et al* (26)

provided for each group of 8 to 9 animals providing ample shade. During a 92-day summer period, the maximum daily average temperature was 96.3 F and the maximum temperature was over 90 F during 77 days. Sprinklers were on from 8:00 a.m. to 5.00 p.m. The average body temperature difference between sprinkled and unsprinkled sows (Table 2) was 2.8 F, and there was a difference of 85 lb in the average 56-day litter weight of the two groups, both in favor of the sprinkled sows.

In a study of individual air conditioning for farrowing sows, Taylor (6) provided each individual farrowing stall with about 8 cfm of air cooled to 50 to 70 F. This was delivered through 4-in. pipes to a location in the stall where the discharge could be conveniently breathed by the sow. Increased animal comfort was indicated by the reduction of rectal and surface temperatures and respiration rates of the cooled sows.

Baby Pigs

According to Newland *et al* (7) the American farmer loses well over a million new born pigs annually from chilling. New born pigs have poorly developed regulatory mechanisms and tend to become more homeothermic after two days of age. The average temperature responses of 25 pigs under barn conditions (environmental temperature between 55 and 75 F) showed that body temperature of a new-born pig drops by 3 to 12 F during the first hours after birth, with the average being about 4 F. The sharpest decline occurs during the first 20 minutes of life. Newland (7) also found a significant correlation between weight of a pig and its ability to adapt itself to its environment.

Taylor *et al* (8) farrowed pigs under controlled temperature conditions ranging from 20 to 60 F. Small weak pigs appeared to chill at 40 F but one litter of strong pigs appeared quite comfortable, and no losses occurred during their first 72 hours of life in a 33 F room. Of 8 pigs farrowed in a 20 F room without supplementary heat, four died from chilling within the first five hours. The remaining four pigs with body temperatures as low as 65 F were revived in a 70 F room under heat lamps and were back to normal in about four hours. Taylor (8) suggests that auxiliary heat should be supplied in farrowing pens at temperatures below 45 F but concluded that supplementary heat would seldom be required to prevent chilling in pigs that are over one week old.

Cairne and Puller (9) measured the metabolic rate of pigs in a gradient-layer direct calorimeter at air temperatures of 59, 68, 77 and 86 F. The pigs studied ranged in size from about 9 to 26 lb. It was found that the critical temperature of these pigs, fed *ad lib,* exceeded 86 F for pigs weighing 13 lb and under and was about 68 F for pigs weighing 22 lb.

Gill and Thomson (10) divided litters into equal groups and provided supplemental heat for half the litter to determine the effect of environment on suckling pigs. From weaning to 200 lb the pigs were all raised in the same environment. They observed: "It is most remarkable that the piglets getting no additional heating were able to withstand the cold. The average temperature was 44 F and, on many occasions, below the freezing point."

In the experiments of Gill and Thomson there was no significant treatment difference in the amount of milk suckled, but the pigs exposed to the lower temperature consumed more solid food before weaning. It is interesting to note that during 53 days of lactation the average milk yield of six sows varied from 445 to 764 lb, or an average of 605 lb. This represents an average yield of about 1.37 gal of milk per day per sow. Post-weaning performance appeared to be unaffected by the preweaning treatment. The average time taken to reach 200 lb was 210 days for the heated group and 212 days for the unheated group. Gill and Thomson suggest that there is probably sufficient savings in extra food consumed and in reduction of pigs crushed by the sow to warrant the use of heat lamps through the first three weeks of pigs life.

Pigs weaned at about two weeks were raised under controlled conditions for three weeks in tests conducted by Muehling and Jensen (11). Test air temperatures of 40, 50, and 60 F were used to compare the effects of heated houses, heat lamps and heat pads, and unheated houses. There were no significant differences in rectal temperatures between treatments. Pigs in pens with an unheated draft-free house gained nearly as fast at 40 F as pigs in pens with heat. In a drafty building, however, where the temperature averaged 50 F but varied considerably, even pigs with access to the various heated areas did poorly.

McLagen and Thomson (12) farrowed and raised pigs in four different natural environments: *(a)* open pens in a "large drafty granite and concrete building" with an uninsulated floor, *(b)* same as *(a)* but with a wooden sleeping platform, *(c)* wooden "ark hut" with an indoor run, and *(d)* wooden "ark hut" with an outdoor run. Pigs raised in environment *(a)* had average weaning weights less than half as much as those farrowed and raised in environment *(d)*, even though the air-temperature difference between these two "best and worst" environments was only about 2 F (42.8 and 44.9 F). Addition of the wooden sleeping platform in the open pen provided a dry bed for the pigs in that pen and their average weaning weight was more than twice that of the pigs in the open pen, and nearly as much as the pigs in the best environment *(d)*. Table 3 shows some results of two tests by McLagen and Thomson. According to the figures in this table, the appetite of the pigs generally decreased with a decrease in air temperature. Environmental factors other than air temperature also influenced growth and appetites of the pigs. Though the open pen with the wood floor had the lowest temperature of all pens during the two tests, the weaning weight of these pigs was nearly the greatest. McLagen and Thomson conclude that the type of flooring provided for pigs to lie on is of great importance, and if this is well insulated, good pigs can be reared in a house with an average air temperature of only 45 F (range may be 33 to 55 F), although "a higher temperature would be safer." They also suggest that it is impossible to rear good pigs in an open pen in a large cold, drafty building. Where pigs were kept on after weaning in environment *(a)* to 16 weeks of age they showed no signs of catching up to the pigs raised in environment *(d)*. Pigs provided with blanket-type jackets by McLagen and Thomson did not grow better than unjacketed pigs in a cold environment. Tests by Lucas and Thomson (13) also indicated the effect upon small pigs of type and temperature of floor.

Growing Hogs

Heitman *et al* (14) determined optimum growing temperatures for hogs raised under constant temperature conditions in a controlled-environment chamber. Hogs ranging in weight from 80 to 450 lb were exposed to temperatures of 40 to 110 F with a relative humidity of about 50 percent and constant air velocity of 25 to 35 fpm. The influence of air temperature and animal weight upon the daily gain of hogs is shown in Table 4. The temperature at which daily gain appeared to be a maximum varied from 61 F for 350-lb hogs to 73.5 F for 100-lb hogs. Rate of gain was sharply reduced when air temperatures were different than the optimum, with the most rapid reduction occurring with temperatures above the optimum. When air temperature was

TABLE 3. FEED CONSUMED BY PIGS FROM BIRTH TO FARROWING

	Experiment A			Experiment B		
	Average air temp., F	Feed per pig, lb	Weaning weight, lb	Average air temp., F	Feed per pig, lb	Weaning weight, lb
(a) Open pens, uninsulated floor	44.5	5.1	25.1	42.8	Less than 1 lb.	16.9
(b) Open pen, wood floor	—	—	—	41.0	19.7	37.3
(c) Hut, indoor run	45.5	10.4	28.2	41.8	Less than 1 lb.	20.5
(d) Hut, outdoor run	48.5	15.7	35.6	44.9	29.2	41.3

TABLE 4. EFFECT OF AMBIENT AIR TEMPERATURE AND MEAN LIVEWEIGHT ON RATE OF GAIN OF SWINE

(Average daily gain in pounds per pig)

Mean liveweight, lb	Air temperatures, F: 40 F	50 F	60 F	70 F	80 F	90 F	100 F	110 F
100		1.37	1.58	2.00	1.97	1.40	0.39	—1.32
150	1.27	1.47	1.75	2.16	1.82	1.14	—0.19	—2.60
200	1.19	1.57	1.91	2.22	1.67	0.88	—0.77	
250	1.10	1.67	2.08	2.14	1.51	0.62	—1.36	
300	1.02	1.77	2.24	2.06	1.36	0.36	—1.95	
350	0.94	1.87	2.41	1.98	1.21	0.10	—2.53	

100 F, all pigs 150 lb or greater lost weight; 100-lb pigs lost weight at 110 F. The daily rate of gain of any size pig tested was 2.0 lb or greater at the "optimum" temperatures.

The effect of temperature on growth rate and feed consumption of swine is well exemplified in unpublished data of E. F. Johnson, presented by Warwick (15), showing results of experiments with pigs maintained at 50 or 90 F. Where 150-lb pigs were kept on test for 32 days those maintained at 90 F gained less than ⅓ lb per day and used nearly 1,000 lb of feed per 100 lb of gain. In a test with pigs from weaning to 200 lb, the weight gains of the group kept in the 90 F environment averaged 0.35 lb per day less than those of 50 F group, but their feed consumption per 100 lb gain was only slightly increased.

The need for methods of counteracting high-temperature effects has been long recognized by practical hog producers. In Texas tests reported by Jackson (16) pigs with access to a wallow gained 14 lb more per day over a 90-day summer period than animals with no wallow. Bray and Singletary (17) reported that pigs in Louisiana tests with either a portable or mud wallow gained about 0.4 lb per day more than control pigs. Sprinklers for fattening hogs in Georgia were tested by McCormic *et al* (18). Hogs in dry lots that had access to sprinklers gained about 0.3 lb more daily during 50-day test periods than unsprinkled pigs. Purdue tests reported by Andrews (3) have shown increased daily gains of 0.2 to 0.3 lb for sprayed pigs of more than 100 lb in weight. For 150-lb hogs, access to a mechanically cooled concrete slab increased their gains 0.3 to 0.4 lb daily in the Purdue tests. Heitman *et al* (19) reported significant increases in average daily gains due to *(a)* a wallow in the sun, *(b)* a wallow in the shade, and *(c)* a wallow in combination with increased air flow from a fan, during a 70-day summer test period with an average air temperature of 75 F. In the same test a group of pigs raised in confinement inside a farrowing barn also gained significantly faster than the control group in an outside shaded concrete lot. There were, however, no significant differences in the weight gains between the treatments. Kazarian *et al* (20), in Michigan tests, compared the growth rate and feed efficiency of pigs raised *(a)* unconfined, with conventional hog house, *(b)* confined in a ventilated house with double-pane windows, and *(c)* confined in an air-conditioned house with double-pane windows. Results of tests during a 14-week summer period showed that hogs housed under improved conditions had a 10 percent increase in their growth rate as well as a 10 percent increase in feed efficiency. Air conditioning improved the environment but did not produce additional increases in gain or feed efficiency.

From a survey of cold-weather housing made by Inglis and Robertson (21), an analysis was made of housing conditions that were conducive to growth of pigs. Their data are presented in Table 5. They found that the health of pigs could be correlated with the inside-outside temperature difference. On the basis of their results they recommend that a hog building for winter housing should be designed for a minimum air-temperature difference of 12 F between inside and outside. They also suggest that the building volume, per 200-lb pig, should be no greater than 150 cu ft and the amount of air change should be less than 800 cu ft per hr.

TABLE 5. INFLUENCE OF COLD WEATHER HOUSING CONDITIONS ON THE GROWTH OF SWINE

Housing conditions		Average*	Range
Mean temperature difference inside to outside, F	A†	13.3	9.7 - 17.2
	B	5.9	2.0 - 8.7
Volume per 200 lb pig, cu ft	A	63.0	17 - 137
	B	500.3	48 - 1780
Floor area per 200-lb pig, sq ft	A	17.8	4.3 - 34.0
	B	51.0	19.0 - 139.0
Building surface area per 200-lb pig, sq ft	A	66.5	19 - 135
	B	160.0	52 - 390
Air supply, cu ft per hr per 200-lb hog	A	1340	239 - 2300
	B	8955	787 - 43,000

*Average condition for all houses where pigs were observed to be either thriving or not thriving.
†A, pigs thriving; B, pigs not thriving.

Lamont *et al* (22) cite cases where cold-weather pig mortality, up to as high as 40 percent, was reduced to an average of 1 percent by *(a)* relaying concrete floors to provide air space underneath, *(b)* continuing pen partitions to the ceiling, *(c)* sheeting off the central alley from the pen, and *(d)* providing an air space between the ceiling and outer roof. An analysis of production of 38 pig farms by Clarke (23) indicated a greater fattening efficiency both winter and summer for pigs confined indoors compared with pigs that had a hut with free access to outside runs.

In studies of heated floors during cold weather, Barber *et al* (24) found no benefit from floors with surface temperatures increased about 10 F by electric heat, in a series of tests with pigs of weights ranging from 35 to 190 lb.

Light duration, as a swine environmental factor, was investigated by Braude *et al* (25). Their results are summarized in Table 6 and indicate that the different light treatments used did not influence the performance of the pigs.

TABLE 6. EFFECT OF LIGHT ON SWINE PERFORMANCE

	Dark, 24 hr	14 hr L* 10 hr D	10 hr L 10 hr D	Light, 24 hr
Group I (9-19 weeks)				
Final weight, lb	129.0	124.2	125.9	127.8
Daily gain per pig, lb	1.3	1.2	1.3	1.3
Feed per pound gain, lb	2.8	2.9	2.8	2.9
Group II (9 weeks to market)				
Final weight, lb	205.2	201.2	203.5	202.0
Daily gain per pig, lb	1.4	1.3	1.3	1.3
Feed per pound gain, lb	3.3	3.4	3.4	3.4

*L, light; D, dark

Kelly *et al* (26) investigated the effect of heat loss on hogs in a psychrometric chamber. Heat loss rates by radiation, convection, and conduction were measured at environmental temperatures between 40 and 100 F. These measurements were made with heat flow meters and appropriate radiometers. They determined that, for an individual hog, approximately 20 percent of its surface contacts the floor to lose heat by conduction, 80 percent is exposed to the air to lose heat by convection, and approximately 75 percent is exposed so as to lose heat to another surface by radiation. For the inside hogs of a huddled group, they estimated that 20 percent contacts the other animals, 40 percent loses heat by convection and 35 percent by radiation.

Hog surface temperatures, as affected by environmental temperatures, were also measured by Kelly (26). Straight-line relationships were found such that at 100 F the surface temperature varied from 103 F for a 75-lb hog to 99 F for a 300-lb hog. At 40 F the surface temperatures were 90 and 74 F, respectively.

Additional heat and moisture-loss measurements for swine were made by Bond *et al* (2) in a single-chamber calorimeter. With the low air velocities used (25 to 35 fpm) the quantity of heat lost by convection and radiation was about equal; conduction amounted to about 10 percent of the total heat lost. The rate of heat lost by evaporation decreased from a maximum of about 90 percent of the total at 100 F to a minimum of about 15 percent at the lower temperatures (40 to 50 F). Since management conditions of the test were similar to practical hog house conditions, measurements of the moisture removed by the ventilation system of the chamber provide latent heat and moisture removal estimates necessary for hog house ventilation design problems.

In a report by these same investigators, Bond, Kelly, and Heitman (27), multiple, curvilinear regression curves were developed (Fig. 3) to provide a means of estimating total heat loss from pigs weighing 50 to 400 lb at ambient air temperatures ranging

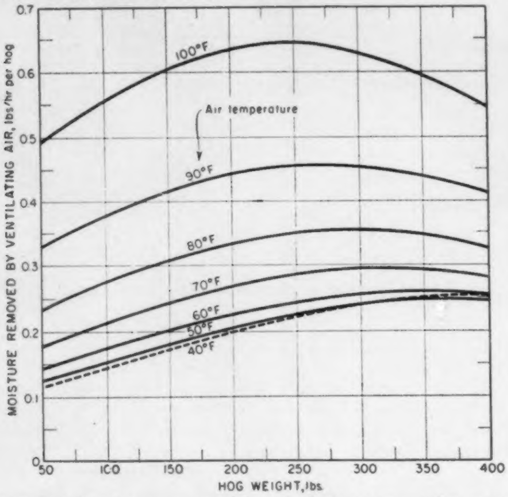

Fig. 3 Total moisture removed by ventilation system of test room. Bond, Kelly, and Heitman (27)

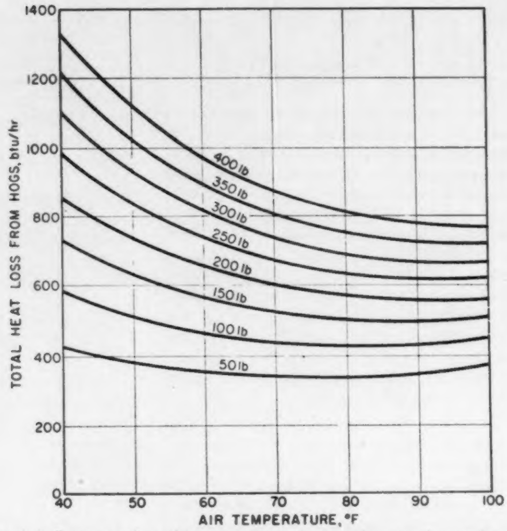

Fig. 4 Influence of ambient temperature and animal weight on total heat lost by swine. Bond, Kelly and Heitman (27)

between 40 and 100 F. The equation for estimating total heat loss is

$$Y = 2.477 + .034x_1 - 0.577x_2 + 0.148x_1^2 + 0.710x_2^2 - 0.313x_1x_2$$

where Y = log heat loss, Btu per hr per pig
x_1 = log body weight, lb
x_2 = temperature/100, deg F

A similar series of curves was developed (Fig. 4) showing the amount of moisture removed by the ventilation system of the test calorimeter for varying hog weights and ambient temperatures. The equation that follows of this series of curves provides a method of estimating the amount of moisture a ventilation system will be required to remove and the amount of latent heat that must be considered in the design of building insulation, heating, and air conditioning. The moisture loss estimation curve is

$$Y = -0.961 + 0.291x_1 - 0.785x_2 - 0.146x_1x_2 - 0.029x_1^2 + 1.375x_2^2$$

where Y = log of water loss, lb per hr
x_1 = weight/100, lb
x_2 = air temperature/100, deg F

These same investigators determined the percent of the total heat that was lost by each of the four methods; radiation, convection, conduction, and evaporation. These values are shown in Table 7.

Robinson and Lee (28) studied the reactions of pigs weighing bout 130 lb to short-time exposures (up to 7 hr) at high air temperatures and high humidities. With intermediate degrees of heating up to 90 F, the rectal temperature increased but progressed toward equilibrium. With higher degrees of heating, the rectal temperature increased rapidly without showing an indication of establishing an equilibrium. Below a dry bulb temperature of 85 F neither temperature nor humidity produced any regular effect upon rectal temperature. At 95 F the pigs generally had to be removed from the test room before seven hours had elapsed when the humidity was 65 percent or over. At 105 F and above the pigs were not able to tolerate any atmosphere for seven hours. The degree of humidity had little regular effect upon the pig reactions until temperatures were 95 F or higher. There was no evidence of acclimatization developing in response to repeated exposure in either a hot-wet or a hot-dry atmosphere. Rectal temperatures of 107 F and respiration rates as high as 280 per minute were noted. They were not kept in the room beyond this stage. Sousing stressed pigs with water reduced their rectal temperature 3 F in 10 min, and reduced their respiration rate from 280 to 100 per minute.

Basic studies relating environment and physiological reactions of swine are presently being conducted in the new piggery climate laboratory of the Danish National Institute of Building Research at Roskilde, Denmark. Some results from these studies have been summarized by Sorensen (29).

TABLE 7. PERCENT OF TOTAL HEAT LOST FROM HOGS BY RADIATION, CONVECTION, CONDUCTION, AND EVAPORATION

Room temperature, F	Percent of total heat lost			
	Radiation	Convection	Conduction	Evaporation
40	34.9	37.8	12.8	14.5
50	33.0	38.7	12.8	15.5
60	32.9	38.7	11.8	16.6
70	27.0	34.3	10.7	28.4
80	23.0	52.0	7.7	37.3
90	17.2	20.7	7.4	54.7
100	2.6	5.0	2.8	89.6

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Environmental Studies with Sheep

C. F. Kelly
Fellow ASAE

POSSIBLY fewer studies have been made of the effect of environment upon sheep than with any other class of farm livestock. This is due to the fact that sheep are not, as a general practice, protected from the weather in dry climates because of the heavy insulating value of their wool. However, a few groups of research workers, mostly physiologists, have studied the response of sheep to thermal and other environmental factors.

Heat Production. Ritzman and Benedict (10, 11)* studied the basal and "standard" metabolism of sheep in connection with determining the energy of feeds. As a comparison, they made, in their respiration chambers, measurements of heat production shortly after feeding (0 to 4 hr). Armstrong *et al* (1) made a series of calorimetric measurements designed to study the effect of environmental temperature on the energy expenditure and food utilization of adult Halfbred x Down wethers. Their respiration apparatus was arranged so that air temperature equaled wall temperature; the air relative humidity varied between 45 and 55 percent, and the air velocity was low and constant. The sheep were clipped closely at weekly intervals to maintain fleece length constant and minimal at 0.1 cm. Three levels of feed energy were studied.

Some of the results of Ritzman and Benedict (10, 11) and Armstrong *et al* (1) are presented in Figs. 1 and 2 as being as typical examples of sheep heat production under farm conditions as can be found in the literature. Fig. 1 shows the relation between environmental temperature (47 to 100 F) and heat production. Fig. 2 indicates the effect of animal weight upon heat production at one temperature, 70 F. The sensible and insensible heat was not separated.

Armstrong *et al* (1) also studied the effect of fleece length upon heat production by sheep. At an environmental temperature of 68 F, heat production decreased rapidly and exponentially from a maximum of 380 Btu per hr with a closely clipped fleece to a minimum of about 248 Btu per hr when the fleece had grown to a length of 20 to 30 mm. When the temperature was decreased to 46 F, the range in heat production was from about 520 Btu per hour with closely clipped fleece to 265 Btu per hour when the fleece had grown to 45 mm. These studies were at the medium level feed energy.

Brody (2) gives the calculated resting and basal metabolism of sheep (wethers) at ages 2 to 30 months. "Resting" metabolism is defined as being made up of two components, basal metabolism and specific dynamic action (an energy waste incident to food utilization).

Surface Area. Ritzman and Benedict (9) found, by the surface integrator method, that the surface area of unshorn sheep followed the law: $S = 0.124\ W^{0.561}$, where S equals surface area in square meters and W equals live body weight in kilograms.

Physiological Reactions. Ritzman and Benedict (10) obtained body temperatures of fifty of their sheep at different times. They found that the body temperature of sheep was about 102.5 F, slightly higher

(Continued on page 551)

Report prepared for the special use of the Technical Advisory Committee on Plant and Animal Husbandry jointly sponsored by the American Society of Agricultural Engineers and the American Society of Heating and Air Conditioning Engineers, March 1958 (revised December 1958).

The author — C. F. KELLY — is professor of agricultural engineering, University of California, Davis, California.

*Numbers in parentheses refer to the appended references.

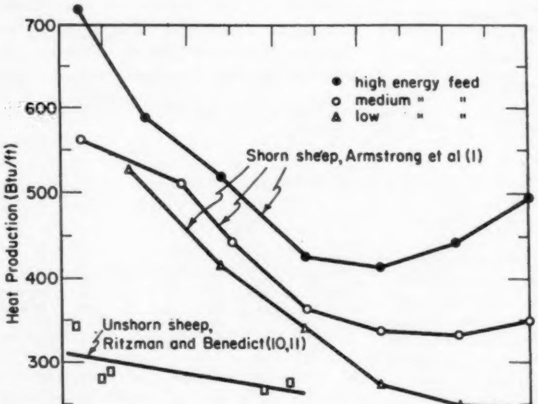

Fig. 1 Effect of air temperature upon heat production of sheep

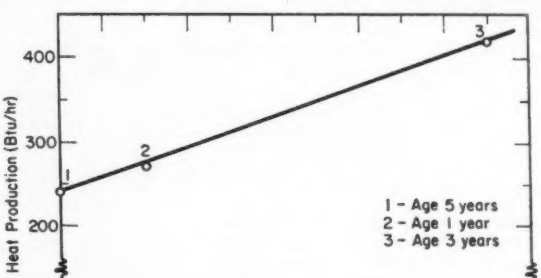

Fig. 2 Effect of sheep weight upon heat production at air temperature of 70 to 72 F (10, 11)

Criteria for Appraising the Performance of Irrigation Pumping Plants

Paul E. Schleusener and **John J. Sulek**
Member ASAE *Assoc. Member ASAE*

IRRIGATION pumping plants supplied water to two-thirds of Nebraska's 2½ million irrigated acres in 1957. The number of acres irrigated from wells increased 290 percent in the past 5 years. The number of wells in use increased by 230 percent. The 22,000 wells in the state were pumped from 600 to 3,000 hr annually. Such rapid expansion of pump irrigation in Nebraska suggests the need for a critical and repeated appraisal of pumping plant efficiency to maintain high standards of equipment performance and economic operation.

Paper presented at the Winter Meeting of the American Society of Agricultural Engineers at Chicago, Illinois December 1955, on a program arranged by the Soil and Water Division. Published with the approval of the Director as Paper No. 876, Journal Series, Nebraska Agricultural Experiment Station.

The authors—PAUL E. SCHLEUSENER and JOHN J. SULEK—are associate professors of agricultural engineering, University of Nebraska.

Acknowledgment: Part of the data used in this paper was obtained under the direction of J. F. Schrunk, formerly instructor in agricultural engineering, University of Nebraska.

An appraisal of pumping plant efficiency can be accomplished by measuring the field performance of the plant and comparing it with a standard or criterion of performance. Field performance is expressed in terms of water horsepower hours per gallon of fuel. It is calculated as follows:

$$\frac{\text{gpm} \times \text{total head (ft)}}{3960} \div \frac{\text{gal fuel used}}{\text{hr}}$$

Measuring Pump Performance

The criteria for appraising the performance of irrigation pumping plants were calculated for deep-well irrigation pumping plants powered by engines using the common fuels and by electric motors. The average specific fuel consumption of the engines using common fuels was obtained from the Nebraska Tractor Tests(7)* and from data supplied by engine manufacturers(3, 4). The efficiency of electric motors, turbine pumps, and drive units was obtained from data supplied by manufacturers (1, 5, 6, 8, 9). The performance characteristics of the individual units making up a pumping plant were then combined in a calculated performance criteria, Table 1. Since only current values of efficiency were used, the criteria will change as improvements are made in the efficiency of the component parts.

The calculated criteria were used as the basis for appraising the field performance of each of the 209 pumping plants tested. These field performance tests were made under actual operating conditions without adjustments or corrections. About 3 percent of the pumping plants tested were found to be operating more efficiently than the level established by the calculated criteria. The instances where field performance exceeded the criteria re-emphasized the fact that the calculated criteria are based upon average performance values of individual components of the pumping plant rather than upon the most efficient performance possible.

The need for periodic appraisal of the pumping plants is indicated by the wide range of performance of the plants, Table 2. The most efficient pumping plants—those operating above the criteria—were powered by diesel engines and

*Numbers in parentheses refer to appended references.

TABLE 1. CRITERIA FOR APPRAISING THE PERFORMANCE OF DEEP-WELL IRRIGATION PUMPING PLANTS

Fuel	Rated load, hp-hr/unit of fuel for representative power units	Performance Criteria, whp-hr per unit of fuel**
Diesel	14.58 per gal.‡	10.94 per gal
Gasoline	11.55 per gal.‡	8.66 per gal
Tractor Fuel*	10.48 per gal.‡	7.86 per gal
Propane	9.18 per gal.‡	6.89 per gal
Natural Gas†	88.9 per 1000 cu ft.‖	66.7 per 1000 cu ft
Electric	1.180 per kw-hr#	0.885 per kw-hr

*40 ASTM octane rating and weight 6.63 lb per gal.

†1000 Btu per cu ft.

‡Average of specific fuel consumption values for power units suitable for irrigation pumping. Taken from Rated Load Belt Test (Test D) of the Summary of Results of the Nebraska Tractor Tests, January 1, 1958(7). Drive losses are accounted for in Tractor Test Data.

‖Manufacturers' data and unpublished engine test data (2, 3, 4). Data corrected for a 5 percent drive loss.

#Manufacturers' data without a drive loss correction as a direct connection is assumed (1, 5, 8). Equivalent to an 88 percent motor efficiency.

**Based on hp-hr per unit of fuel data and a turbine pump efficiency of 75 percent. This is representative manufacturers' laboratory data adjusted for hydraulic column and power shaft losses for 8-in. column at 100-ft bowl setting (6, 8, 9).

TABLE 2. FREQUENCY DISTRIBUTION OF DEEP-WELL IRRIGATION PUMPING PLANT PERFORMANCE COMPARED WITH THE CRITERIA
(Number of Units)

Power Source	Percent that field performance is of performance criteria																				Total
	120 to 125	115 to 120	110 to 115	105 to 110	100 to 105	95 to 100	90 to 95	85 to 90	80 to 85	75 to 80	70 to 75	65 to 70	60 to 65	55 to 60	50 to 55	45 to 50	40 to 45	35 to 40	30 to 35	25 to 30	
Diesel	1	–	–	1	2	–	6	6	8	8	4	4	1	1	1	1	1	–	–	–	45
Gasoline	–	–	–	–	–	–	–	1	–	1	2	3	2	3	4	4	2	1	1	2	26
Tractor Fuel	–	–	–	–	–	–	1	–	–	3	4	1	2	2	2	1	2	–	–	1	19
Propane	–	–	–	–	–	1	–	2	5	3	6	5	5	–	1	2	1	–	–	–	31
Natural Gas	–	–	–	–	–	1	–	3	1	–	2	2	2	–	–	1	–	3	–	–	15
Electric	–	–	–	–	2	9	12	13	11	7	7	5	1	2	2	2	–	–	–	–	73
Total	1	–	–	1	4	11	19	25	25	22	25	20	13	8	10	11	6	4	1	3	209
Accumulative Percent	–	–	–	1	3	8	17	29	41	52	64	73	79	83	88	93	96	98	98	100	

electric motors. The lowest efficiencies were obtained on plants powered by gasoline and tractor fuel. Twelve percent of the deep-well pumping plants tested in Nebraska were found to be using two to four times as much fuel as would be required by a plant properly planned and carefully maintained.

Economics of Efficiency

A high level of efficiency of the irrigation pumping plant is economically important to the individual irrigator and of national importance from the standpoint of the conservation of fuel resources. For example, if a typical irrigation pumping plant in central Nebraska annually uses about 9,000 gal of propane, a saving of 2,000 gal of propane is possible if the pumping plant is installed properly and adjusted to operate efficiently. Improving the efficiency level of Nebraska's 22,000 deep-well irrigation pumping plants from the over-all test average to a high level of efficiency would result in an annual saving of more than $3 million in fuel costs for pump irrigators in Nebraska.

The need for appraising the performance of irrigation pumping plants caused the organization of twelve Deep-Well Irrigation Associations in Nebraska. These represent 40 percent of the deep-well irrigators in the state. Ten of these associations have employed a technician, trained by the Extension Service, to obtain the data necessary for appraising the field performance of irrigation pumping plants. Field performance data are now being taken by a number of well drillers who also serve as equipment dealers. The rapid acceptance of the performance criteria by irrigators and by equipment dealers is further evidence of the practical application of the data reported in this paper.

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. . . Environment for Sheep

(Continued from page 549)

than that of cattle, and that young growing sheep appear to have a slightly higher temperature than old sheep (over two years of age). There was little difference between light and heavy wooled sheep.

Minimum heart rates taken seven to eight hours after feeding followed the same pattern.

Dutt and Hamm (3) divided a group of six sheep into three pairs of two each. One pair was kept as a control and the remainder used for measuring the effects of one week at 90 F, 60 to 65 percent relative humidity, and air velocity of 20 to 60 fpm upon fertility, respiration rate, pulse rate, and body temperature, the results being as follows:

		Environment				
Pair	Treatment	Temperature deg F	Relative humidity percent	Respiration rate per min	Pulse rate per min	Body temperature
I	Control	37-55	---	35	Normal	Normal
II	Sheared	90	60-65	134	Increased	Increased
III	Not sheared	90	60-65	178	Decreased	Increased

The motility of the sperm was less and number of abnormal cells was greater in pairs II and III than in pair I. It took eight weeks to return to normal.

Lee and Robinson (6) found that only above an environmental temperature of 90 F did changes in relative humidity affect rectal temperature, and also at any constant relative humidity above 90 F, the rectal temperature rose with increases in dry-bulb temperature alone.

Findlay (4) summarizes the work of others with respect to the effects of temperature upon evaporative loss and function of the skin, humidity of fleece, etc.

Climate and Wool. Sheep are classed by Hammond (5) into three types: the temperate type, the northern desert sheep, and the southern desert sheep. The temperate-type sheep have thick and compact wool coats, suited to their environment. The coats of the northern desert sheep are coarser and less compact, and of the southern desert sheep consists only of fine short hair similar to that of zebu cattle. Wilson (14) observed that in cold countries animals tended towards the fleecy coat of the sheep, whereas in warm regions hair was more strongly developed and wool absent. This has to do, however, with the adaptation of a breed to an environment, rather than the effect of environment upon wool production. J. F. Wilson (13) states that *shrinkage* (the percent of weight of grease wool lost in the process of scouring) is influenced by the climate the sheep run in, and the amount of dried perspiration. "Shrinkage may vary from as little as 25 percent in very coarse wools, grown where sheep are subjected to heavy rains over long periods, to well over 70 percent in fine wools produced in sections of the country where sand storms are common."

Effect of Light. Hammond (5) has summarized the observations of Sykes and Cole (12) and Yeates (15) upon the relation of light to the sexual season of sheep. "Light plays the major role in regulating the reproductive pattern of sheep."

General. Lee (7) suggested that the grazing sheep "receives more solar radiation than does man when the sun's altitude is high, but less when it is low. It is, therefore, more subject to solar heating than man in hot weather and less in cold weather."

Riek *et al* (8) states that "It is evident that the sheep is amongst the most tolerant of domestic animals to rise of air temperature."

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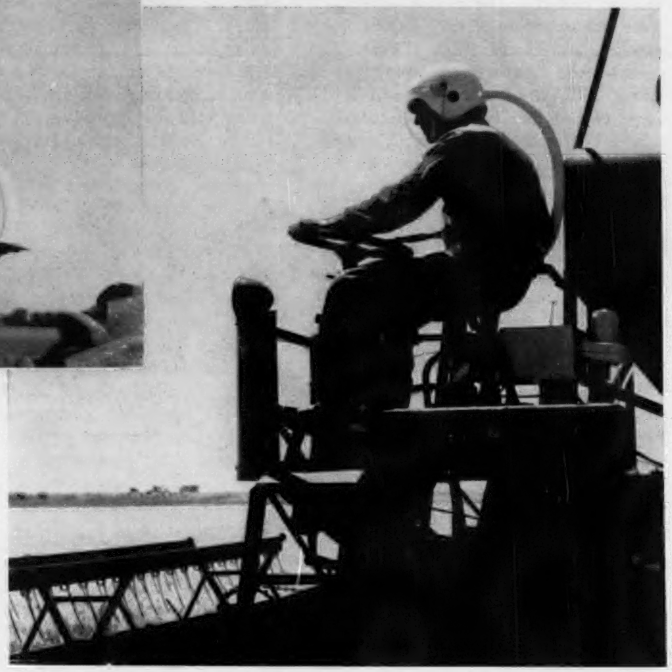
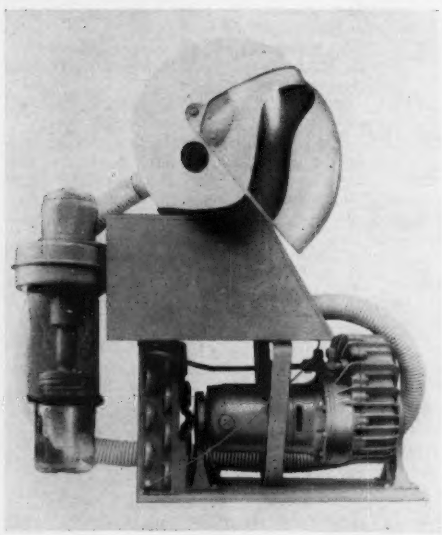


Cool Head for Hot Days with Air-Conditioned Helmet

★

An Idea Sprouting from Space-Age Technology Promises Cool, Summer Comfort for Farm Workers

★



Basic components of the Whitecap are the helmet, flexible vinyl connecting hose, a refrigeration unit and a filter. The unit's electric motor wires into any 12-volt ignition circuit or into a converted 6-volt system

THE operators of the vehicles shown on this page are not of the new order of space pilots suddenly "come down to earth," perhaps to help "dad" over the hump with some of the seasonal farm work. These men are simply sporting Whitecaps, new air-conditioned helmets developed by an agricultural-minded engineer with wide experience in the field of electronics and allied manufacturing, and with a special interest in the possibilities for the application of space-age technology to the needs of agriculture. Manufacturers are the Jamieson Laboratories, Inc., Santa Monica, Calif.

The helmet is made of lightweight fiberglass, and, as an aid to safety for the operator, it is provided with a faceplate of clear shatter-proof plastic that gives good protection against flying objects. A flexible vinyl air hose connects the helmet to a refrigeration-filter unit which is driven by a small electric motor. The unit can be readily transferred from one machine or implement to another, thus making it possible for any piece of tractor-operated equipment to be "air-conditioned." The electric motor wires into any 12-volt ignition circuit or into a converted 6-volt system. Cooling capacity is 1,200 Btu's per hour maximum; blower output is 5 cfm. The unit's centrifugal type filter is reported as 95 percent efficient on material 10 microns and larger.

This one-man air-conditioner is an outgrowth of the research on space suits. Not only does it cool and dry the air, but it reportedly filters out dust, pollen, chaff, fungi and insects. Clean, cool air circulates inside the helmet around the head and face of the wearer, thereby helping him to feel comfortable all over, even on the hottest day. It is further claimed for this air-conditioned unit that, under specially humid conditions, it effectively removes excess moisture from the air by condensation on the cooling coils.

It's interesting to design with concrete

Creative building designs reflect the imagination of the designer and the skillful use of structural materials. Materials available only in set sizes and shapes limit creativity. Concrete does not. Concrete members can be designed in many sizes and shapes to satisfy one specific requirement.

This is the third of a series of reports showing design techniques with concrete applied to specific parts of a building. The paragraphs and tables that follow show simple design methods for reinforced concrete beams. These methods are approximate but result in safe, economical designs.

Beams . . . a size and shape for every need

Beams of many shapes, such as rectangular, tee, I, box, double tee and channel are commonly used in construction. As shown in the example, the simplest of these, the rectangular and tee shapes, can be built in many different sizes that will carry a set load. It is readily apparent that the dimensions are strictly dependent on the needs and wishes of the designer. This freedom makes the design job interesting and permits real creativity.

Rectangular beams range from deep and narrow to wide and shallow. A deep beam requires less reinforcement and is usually the most economical. The beam depth should not be more than three times its width, and lateral support or bridging to prevent buckling is needed at intervals not greater than 32 times the beam width.

At the other extreme, the wide shallow beam is useful in locations of limited headroom. No limitations on width prevail; in fact, a reinforced concrete slab is designed as a series of wide flat beams.

Tee beams provide a wide compressive area with only a limited stem width in the tensile area. As may be seen by comparing Tables 1 and 2, a tee section will carry moments approximately equal to those carried by a rectangular beam of similar width and depth. However, the amount of concrete used in the tee section is considerably less than in the comparable rectangular section.

Most tee beams are a part of a concrete floor system where the slab and beam are built integrally. Under such conditions the maximum flange width "b" allowed in design is the least of the following:

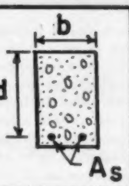
(1) ¼ the span length of the beam,
or (2) 16 times the flange thickness "t" plus the stem width "b′,"
or (3) the center to center distance between parallel tee beams.

For isolated tee beams where the tee shape is used solely to provide additional compressive area, the maximum allowable flange width "b" is 4 times the stem width "b′." The flange thickness "t" shall be not less than one half the web thickness "b′."

Use of Tables 1 and 2

Tables 1 and 2 are useful to (1) design reinforced concrete beams and (2) determine the approximate moment capacity of beams of known size and reinforcement.

RECTANGULAR BEAM
TABLE 1



TEE BEAM
TABLE 2

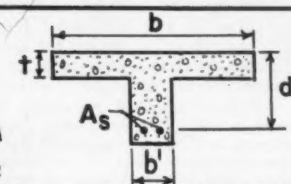


Table 1: $\frac{A_s}{bd}$	Table 1: $\frac{M}{bd^2}$	Table 2: $\frac{A_s}{bd}$	Table 2: Range of $\frac{t^*}{d}$	Table 2: $\frac{M}{bd^2}$
0.005	7.1	0.005	0.08 to 0.27	7.6
0.006	8.6	0.006	0.09 to 0.29	9.0
0.008	11.5	0.008	0.13 to 0.32	11.9
0.010	14.4	0.010	0.18 to 0.36	14.6
0.012	17.2	0.012	0.25 to 0.38	17.4
0.014	19.6	0.014	0.41 to 0.41	19.6

ASSUMPTIONS AND UNITS:

3,000 psi concrete (1,350 psi allowable compression).
20,000 psi allowable steel stress in tension.
b, d and t are in inches.
M is in foot pounds.
A_s is in square inches.

*The lower values of $\frac{t}{d}$ may be controlled by factors other than the load-carrying ability of the beam. (See discussion under Tee beams.)

Procedure for Design:

(1) Choose any $\frac{A_s}{bd}$ from Table 1 (or Table 2 for tee beams). The lower values will give smaller amounts of reinforcement and resulting deeper beams. The higher values approach a balanced design with concrete and steel both stressed near the design limit.

(2) Read the corresponding constant for $\frac{M}{bd^2}$.

(3) Solve for combinations of b and d. With these known, solve for A_s.

Design Example

Problem: Design a rectangular beam for a moment of 20,000 ft. lb.

(1) Choose $\frac{A_s}{bd}$. Say 0.005

(2) Therefore, $\frac{M}{bd^2} = 7.1$

$$\frac{20{,}000}{bd^2} = 7.1\ bd^2 = 2{,}820$$

(3) Set up table of combinations of $bd^2 = 2{,}820$

b	d	$A_s = 0.005\ bd$
8	18.7	0.75
10	16.8	0.84
12	15.4	0.92
24	10.8	1.30

Smaller beams with more reinforcement can be designed by starting with a larger value of $\frac{A_s}{bd}$. Tee beams with many different flange widths and thicknesses can be similarly determined from Table 2.

Cautions: (1) The dead load moment of the beam must be included in the total design moment. (2) Shear and bond stresses should be checked by methods described in ACI 318-56, "Building Code Requirements for Reinforced Concrete."

For more information on reinforced concrete design, write for free booklet, distributed only in the U.S. and Canada.

PORTLAND CEMENT ASSOCIATION

Dept. A9-1, 33 West Grand Ave., Chicago 10, Illinois

A national organization to improve and extend the uses of concrete

Agricultural Engineering Education News Invited

Howard L. Wakeland has been designated as editor of the Agricultural Engineering Division, American Society for Engineering Education. He has also been appointed a member of the ASEE Editorial Committee.

In these capacities he invites contributions of news items, comment, professional papers, and reports relating to agricultural engineering education, for consideration for publication in the Journal of Engineering Education. Contributions should be addressed to Howard L. Wakeland, Assistant Dean, College of Engineering, University of Illinois, Urbana, Illinois.

Outstanding Record Made by AE Graduates at Nebraska

An outstanding record is exemplified by the twelve 1959 graduates in agricultural engineering at The University of Nebraska. Sigma Tau, the honorary fraternity for the College of Engineering, had eight out of the twelve graduates as members. Six of the twelve were elected to membership in Sigma Xi, while nine of the twelve were represented in either Sigma Tau or Sigma Xi. The two men not recognized in an honorary engineering or honorary scientific fraternity ranked above the average in the graduating class in the College of Engineering. A $1100 scholarship was granted to one graduate. Three of the twelve are going ahead with graduate work. Of 32 undergraduates elected to Sigma Xi during the spring semester, six of 16 engineers were agricultural engineers.

Opens Farm Equipment Research and Engineering Center

International Harvester Co. in July officially opened its new million dollar farm equipment research and engineering center at Hinsdale, Ill. The 10-acre structure, which took two-and-one-half years to build, brings under one roof nearly all of the scientific and technical staffs responsible for creating, designing and testing the company's farm and industrial tractors and farm implements of all types.

The new building contains approximately 455,000 sq ft of floor space — 101,000 sq ft is used by research and engineering laboratories; 169,000 sq ft for experimental shops; and 100,000 sq ft for offices and drafting rooms. The remainder is devoted to service departments.

All of the company's farm equipment advanced engineering and all farm equipment product engineering, except that at East Moline and Memphis Works, will be centered at the new facility.

At its peak, employment at the center is expected to be about 1,500 people. Administration and operation of the center is under the direction of William W. Henning, manager of engineering for Harvester's Farm Equipment Group. Henning is assisted by W. R. Dalenberg and H. P. Smith, assistant managers of engineering.

Farmway Joins New Holland

To continue its expansion in the farmstead mechanization field, New Holland Machine Co. has purchased the Farmway Co. of Manawa, Wis., manufacturer of silo unloaders and barn cleaners. In announcing the purchase, George C. Delp, president of New Holland, said that the transaction includes the company's factory at Manawa, and Farmway's major products. Carl Dretzke, founder and president of Farmway, will remain in charge of the Manawa operation as general manager.

Chrysler Adds Diesel Engines to Sales Line

A complete line of diesel engines will be added to the Chrysler's Marine and Industrial Engine Division sales line, according to an announcement by Arthur S. Hudson, president of the division. An agreement has been signed with Klockner-Humboldt-Deutz of Germany, one of the largest diesel manufacturers in the world, and its subsidiary in the United States, Diesel Energy Corp., New York City, to represent their high-speed engines in the U.S.

Oliver Fair

The Hippodrome of Waterloo, Iowa, has been selected as the site of the Oliver Fair at which the farm and industrial equipment manufacturer will present to its dealers the new and improved machines that have been developed for distribution in 1960. The fair will extend from November 13 through December 15. Carl L. Hecker, company president, has announced plans to centralize the annual presentation program, heretofore conducted in a series of branch area meetings.

Scholarships

The first recipient of the Virgil Overholt Scholarship at Ohio State University is Robert McClure. This annual $300 scholarship is provided by Hancock Brick and Tile Co. of Findlay, Ohio, and is awarded to an outstanding and deserving agricultural engineering student.

The Standard Oil of Ohio's $300 annual scholarship at the University of Ohio was awarded this year to Roger L. Badenhop of Hamler, Ohio. Second, third, and fourth place winners are conducted on a three-day all-expense-paid tour of places of outstanding agricultural engineering interest. Funds for this trip are presented by the Ohio Association of Retail Lumber Dealers, Ohio Drainage Contractors Association, Ohio Farm Electrification Council, and the Ohio Tractor and Implement Co. (Ford) Trust Fund.

Establishment of a scholarship fund for University of Vermont students enrolled in agricultural engineering has been announced by the Central Vermont Public Service Corp. The fund, called the Ralph J. Bugbee Scholarship Fund, will award a $200 scholarship each year to deserving students in each of UVM's four classes. The scholar-

(Continued on page 573)

EVENTS CALENDAR

September 12-27—*40th Swiss National Fair,* Lausanne, Switzerland. For further information write to Consulate General of Switzerland, 75 E. Wacker Drive, Chicago 1, Ill.

September 14-17 — *SAE National Farm, Construction and Industrial Machinery Meeting,* Milwaukee Auditorium, Milwaukee, Wis. Write to Society of Automotive Engineers, Inc., 485 Lexington Ave., New York 17, N. Y.

September 16-18 — *Southern Farm Equipment Manufacturers* Ninth Annual Meeting, Sedgefield Inn, Greensboro, N. C. Contact SFEM headquarters at 3224 Peachtree Road, N.E., Room 207, Atlanta, Ga., for details.

September 28 - October 1 — *The American Welding Society* fall meeting, Sheraton-Cadillac Hotel, Detroit, Mich. AWS headquarters at 33 W. 39th St., New York 18, N. Y., may be contacted for further details.

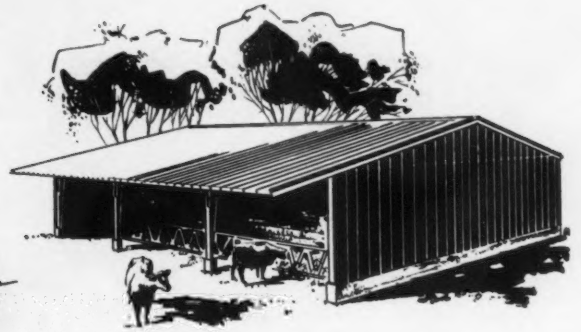
September 28 - October 2 — *National Hardware Show,* The Coliseum, New York City. Additional information may be obtained from NHS executive offices, Suite 1103, 331 Madison Ave., New York 17, N. Y.

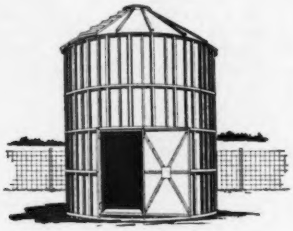
October 4 — Annual Meeting of the *Dairy Society International,* Empress Hotel, Miami Beach, Fla. Additional information may be obtained by writing to DSI, 1145 19th St., N.W., Washington 6, D.C.

October 8-10 — *Mid-American Lawn, Garden & Outdoor Living Trade Show,* International Amphitheatre, Chicago. Complete data and floor plans are available from the Mid-America Lawn, Garden & Outdoor Living Trade Show, 331 Madison Ave., New York 17, N. Y.

October 11-14 — *Farm Equipment Institute* 1959 Convention, Queen Elizabeth Hotel, Montreal, Quebec, Canada. Write to FEI, 608 S. Dearborn St., Chicago 5, Ill., for further details.

October 11-16 — Pacific Area National Meeting of the *American Society for Testing Materials,* Sheraton-Palace Hotel, San Francisco, Calif. Write to ASTM executive offices, at 1916 Race St., Philadelphia 3, Pa., for complete details.





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R. T. Brown


W. R. Mogg


J. A. Kriva


H. A. Parker

Richard T. Brown has been promoted to manager of The Oliver Corp. plant in South Bend, Ind. He joined the corporation in South Bend in 1950, serving successively as a design engineer, assistant chief engineer, and for the past two years as production superintendent. He is a graduate of Ohio State University where he earned B.S. degrees in Agriculture in 1942 and Agricultural Engineering in 1946. From 1942 to 1946 he was in the U.S. Army Corps of Engineers, attaining the rank of captain.

William R. Mogg recently has been promoted from sales manager to general manager of Crucible Steel Company's Spring Division. He will be responsible for all phases of the division's operations, including production, sales, personnel, and administration. Prior to joining the company, he was sales manager of special products at the Cleveland Graphite Bronze Co., a division of the Clevite Corp., where he had been employed since 1940 in various sales, engineering, and production capacities.

J. A. Kriva has been recently appointed works engineer for the main plant of Ceco Steel Products Corp., Cicero, Ill. Previously, he was with the Warner Electric Brake and Clutch Co., South Beloit, Ill., where he held the positions of project engineer and manager of manufacturing engineering. He earned a degree in mechanical engineering from Marquette University, Milwaukee, Wis., in 1943.

Henry A. Parker, formerly sales manager of the Utica, N. Y., branch of The Oliver Corp., has been promoted to regional sales manager of its eastern division. Prior to his position at Utica, he was territory manager of the company's South Bend, Ind., branch. While on leave from this position, he attended the University of Indiana, earning a master's degree in business administration in 1957. He became associated with the A. B. Farquhar Co. of York, Pa., now a division of Oliver, in 1947.

Kenzo Yoshida, formerly research engineer in the farm machinery second division of the agricultural engineering department, Hokkaido National Agricultural Experiment Station, Kotoni, Sapporo, Japan, recently has accepted a position as professor in the agricultural engineering department of the Allahabad Agricultural Institute, India.

Bruce A. Foster has been promoted recently to the position of account executive with Aubrey, Finlay, Marley & Hodgson, Inc. in Chicago. Bruce joined the advertising firm in 1956. Formerly he was associate editor of *Farm Implement News.*

John Ransom, formerly product manager, has been promoted to the position of advertising and sales promotion manager of Minneapolis-Moline Co., Hopkins, Minn. He was born at Davenport, Iowa, and is a graduate of Denison University, Granville, Ohio. He joined the company in 1928, serving as assistant advertising manager until 1932 when he was named sales supervisor at Columbus, Ohio. In 1934, he became advertising manager of B. F. Avery & Sons Co., Louisville, Ky. When Minneapolis-Moline bought the Avery firm in 1951, he was appointed director of product research and training, and in 1957 was named product manager.

Louis M. Glymph, Jr. has been appointed to the post of acting chief of the Watershed Technology Branch, Agricultural Research Service, USDA, Beltsville, Md. Prior to his new appointment, Mr. Glymph was assistant chief.

Leslie D. Lee, who has been associated with the Delmar, Del., plant of the Ralston Purina Co. since 1957, has been transferred recently to the company's plant at Camp Hill, Pa.

Ralph M. Titcomb, formerly with the manufacturing training program of General Electric Co., has been recently placed in the position of quality control engineer for the company's Knoll's Atomic Power Laboratory.

John K. Hale has been recently promoted to product improvement engineer at New Holland Machine Co. In his new position, he has charge of product improvement for all the machines manufactured at the Belleville, Pa., plant. Prior to his new appointment he was staff designer for the company at New Holland, Pa.

NECROLOGY

Alfred J. Wojta, associate professor of soils and agricultural engineering at the University of Wisconsin, passed away July 21, 1959, in a Madison, Wis., hospital after a long illness with cancer. He was born near Menomonee, Mich., in 1909 and reared and educated in Wisconsin, receiving a B.S. degree in agricultural engineering, in 1931, and a B.S. degree in mechanical engineering, in 1932, from the University of Wisconsin. Following graduation, he became a heating and ventilation engineer for a local heating concern. From 1935 to 1946 he was employed by the Soil Conservation Service successively as senior camp engineer, superintendent of four erosion control CCC camps, state safety and equipment engineer, district conservationist and area agricultural engineer.


A. J. Wojta

Mr. Wojta received a civil engineer diploma from the International Correspondence Schools, Scranton, Pa., in 1946, and joined the staff at the University of Wisconsin the same year, as an assistant professor of soils and agricultural engineering. Two years later, he transferred to teaching and research in the agricultural engineering department. In 1953 he received an M.S. degree in agricultural engineering from the University.

Among his many activities, he had been chairman of the Wisconsin Grassland Field Days program and general manager of the Wisconsin Farm Progress Field Days program. In 1947, he initiated, in cooperation with other staff members, the land forming program designed to provide the ultimate in surface water control and ease of working field areas with large modern equipment. Mr. Wojta had also been active as state drainage engineer, a member of the Water Regulatory Board, and a professional engineer.

He joined ASAE in 1939 and served as vice-chairman of the Soil and Water Division in 1952 and as chairman in 1953. In 1954 he was chairman of the Division's Steering Committee; in 1957 served as chairman of the Surface Drainage Committee, and was a nominee for national vice-president for 1958-59. He also held memberships in the American Society of Agronomy, Soil Science of America, Soil Conservation Society, Wisconsin Chapter, and National Society of Professional Engineers, Wisconsin Extension Workers Association, and Alpha Zeta, agricultural honorary fraternity.

He is survived by his wife and a son, Alfred, Jr.

W. O. Beyer, a member of ASAE since 1952, passed away on February 18, 1959, in Pittsburgh, Pa. He was 81 years old and active until the time of his death. Mr. Beyer received the degree of Mechanical Engineer from Cornell University in 1902. He was associated with Jones & Laughlin Steel Corp. from 1905 to 1909, and was employed as a sales engineer with the Dravo-Doyle Co. of Pittsburgh until 1914. His next position, from 1915 to 1933, was district manager of the Pittsburgh office of The Falk Corp. He worked for the City of Pittsburgh as chairman of the Civil Service Commission from 1933 to 1936. At this time Mr. Beyer became interested in the study of irrigation problems and the need for an inexpensive, but practical, form of a quick release pipe coupling suitable for use in distributing water and other fluids under variable pressure, which led to his invention of a special coupling for irrigation systems. Beginning in 1944 and through 1948, he directed and operated production, sales and installation of his patent at the McDowell Manufacturing Co., and up until the time of his death had been retained by them in an advisory capacity.

Pacific Northwest Section

The Pacific Northwest Section will hold its annual meeting October 14-17 at the Ephrata Recreation Center and Grant County PUD Building Ephrata, Wash. Activities will begin Wednesday morning, October 14, with a tour of Priest Rapids Dam, to be followed by a program and social hour in the evening. The general program will begin Thursday morning, October 15, with addresses on contractual relationship with the three Columbia Basin irrigation districts, by Phil Nalder, project manager, Columbia Basin Irrigation Project; the importance of mechanization in modern farming and to the agricultural engineer, by L. H. Skromme, chief engineer, New Holland Machine Co. and national president of ASAE; a look at the poultry industry in the Pacific Northwest, by C. F. McClary, geneticist for Heisdorf and Nelson, Kirkland, Wash.; and agricultural engineering problems in Alaska by C. Ivan Branton, Alaska Agricultural Experiment Station, USDA, Palmer, Alaska.

At a luncheon meeting on Thursday, Ralph Gram, area development manager, Western Power and Development, Ltd., Vancouver, B. C., will speak on agricultural considerations in an area development program. National ASAE president, L. H. Skromme, will be the featured speaker at the luncheon meeting on Friday. His topic will be: "National Affairs of ASAE." H. W. Barlow, director, Washington State Institute of Technology, Washington State University, will be the speaker at the annual banquet scheduled for Friday evening. He will speak on "The Changing Patterns of Academic Research." Presentation of the Student Awards papers will be included in the Friday afternoon meeting.

Thursday afternoon will be devoted to tours. A total of four different tour options have been scheduled. A student dinner, courtesy of R. M. Wade & Co. will be held Thursday evening. Three concurrent sessions will be held also on Thursday evening. The Power and Machinery program will include papers on hay wafering, the history of self-propelled hillside harvesters; problems of the design engineer; and a panel discussion. Subjects to be discussed at a joint Electric Power and Processing and Soil and Water program are: New developments in buried sprinkler systems; experiences with phase converters on irrigation pumping installations; where are we going in soil moisture testing?; and automation possibilities in irrigation. The Farm Structures program will consist of discussions on controlled atmosphere storage of apples; new developments in fruit harvesting; and professional service — how do we give it?

Three concurrent sessions will also be held on Friday morning. C. B. Richey, chief research engineer, Tractor and Implement Division, Ford Motor Co., Birmingham, Mich., will present a paper on an automatic tractor-guiding attachment on the Power and Machinery program. Also included on this program will be a paper on laying plastic drain tile, by J. L. Diamond, agricultural application section, sales development division, Caterpillar Tractor Co., Peoria, Ill., and a panel discussion. The Soil and Water Program will include discussions on surface irrigation efficiency studies; design capacities for sprinkler systems; and weed screens for farm irrigation systems; also progress reports on potato irrigation research demonstration. Subjects to be covered at a joint Electric Power and Processing and Farm Structures program are: Feed mechanization and hay pelleting in California; mechanization of livestock operations and poultry operations; potato handling and storage; and refrigerated potato storage.

A special Ladies' Program is planned with something of interest for each of the three days.

Ohio Section

October 11 and 12 at the Ohio Agricultural Experiment Station, Wooster, is the time and the place of the Ohio Section fall meeting. The two-day meeting will open with a weiner roast and picnic at 5:30 p.m. on Sunday, followed by progress reports of 1960 Convention Committees. At 9:30 a.m. on Monday the dedication and acceptance of the new Agricultural Engineering Building, OAES, will take place. Following the dedication, a business meeting will be held, after which the staff of the new building will discuss the future agricultural engineering research program and the future USDA, ARS, pesticide and equipment research program. A tour of the building and equipment will be made before lunch time. L. H. Skromme, ASAE national president, will be the speaker at the twelve o'clock luncheon. Monday afternoon will be devoted to tours on and near the OAES campus.

Iowa Section

The Iowa Section will meet on Friday evening, October 2, for a dinner meeting at McNeal Hi-Way Hotel, Des Moines, Iowa. Featured speaker will be J. L. French, chief product engineer, John Deere Equipment Works, who will discuss problems in designing light industrial equipment.

Chicago Section

The annual meeting and field trip of the Chicago Section will be held on Tuesday, September 29, at The Thor Research Center, Thor Power Tool Co., Marengo, Ill. For "seeing" attention the program will include the grass incubator, the latest in farm shops, and soil conservation in action. For "listening" attention will be a paper on what's new in tractor testing, by L. F. Larsen, University of Nebraska. For "enjoyment" a luncheon out in the country is scheduled.

Georgia Section

The Georgia Section will hold its fall meeting on November 13 and 14 at the Georgia Center for Continuing Education, Athens. The program is in the process of being formulated and details will be announced later. Special attention is called to the Georgia-Auburn football game on November 14, which members will be able to attend after the close of the meeting.

Hawaii Section

A technical meeting of the Hawaii Section is scheduled for Wednesday, October 14. Three papers will be presented; two of them will deal with the use of strain gage to help solve engineering problems in sugar and pineapple industries; the other one will deal with the soil and water field. For additional details contact Jaw-kai Wang, secretary, Agricultural Engineering Dept., University of Hawaii, Honolulu.

ASAE MEETINGS CALENDAR

September 29—CHICAGO SECTION, The Thor Research Center, Thor Power Tool Co., Marengo, Ill.

October 2—IOWA SECTION, McNeal Hi-Way Hotel, Des Moines, Iowa.

October 2-3 — KENTUCKY SECTION, Mammoth Cave, Ky.

October 9-10 — TENNESSEE SECTION, University of Tennessee, Knoxville.

October 11-12 — OHIO SECTION, Agricultural Experiment Station, Wooster, Ohio.

October 14—HAWAII SECTION. Contact Jaw-kai Wang, secretary, Agricultural Engineering Dept., University of Hawaii, Honolulu.

October 14-17 — PACIFIC NORTHWEST SECTION, Ephrata, Wash.

October 22-23 — ALABAMA SECTION, Enterprise, Ala.

October 24—MICHIGAN SECTION, Michigan State University, East Lansing.

November 13-14—GEORGIA SECTION, Georgia Center for Continuing Education, Athens.

December 16-18 — WINTER MEETING, Palmer House, Chicago, Ill.

June 12-16—ANNUAL MEETING, Ohio State University, Columbus, Ohio.

NOTE: Information on the above meetings, including copies of programs, etc., will be sent on request to ASAE, St. Joseph, Mich.

Michigan Section

The Michigan Section will hold a meeting on October 24 at Michigan State University, East Lansing, preceding the MSU-Indiana football game. Other meetings are scheduled for February 12 in the Detroit area, and on May 6 in Battle Creek when L. H. Skromme, ASAE president, is expected to attend. More details will be available at a later date concerning these meetings.

Power and Machinery Report

(Continued from page 509)

Committee on Tractive and Transport Efficiency

The Committee on Tractive and Transport Efficiency was formed early in 1959 to exchange information and stimulate research in this field. Tractive efficiency (percentage of engine power effective at the drawbar) of current farm tractors ranges from 70 percent down to 35 percent for field operations in various soil conditions. This low level of efficiency offers a challenge and an opportunity to agricultural engineers. Recent tire developments offer possibilities of improvement and this committee hopes to stimulate and facilitate progress. It is under the leadership of Dr. A. W. Cooper, Director of the National Tillage Machinery Laboratory, USDA, Auburn, Alabama, and is composed of representatives of the tractor manufacturers, the tire manufacturers and public service researchers in this field.

In summary, the Power and Machinery Division is moving ahead with increased committee and program activity in order to help maintain and enhance the leadership of agricultural engineers in the area of crop production equipment.

Respectfully submitted,
C. B. RICHEY,
1958-59 chairman.

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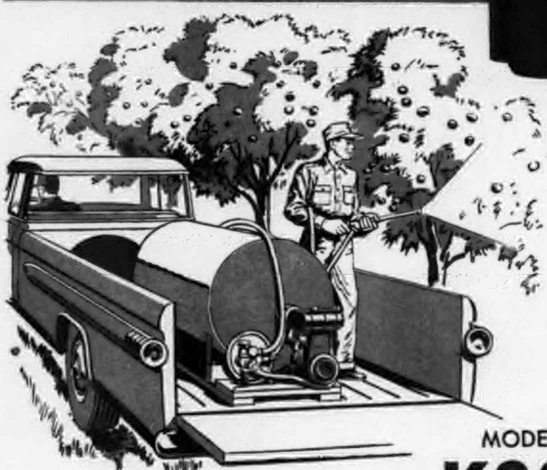

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Four-Purpose Hog Pen

Starline, Inc., Harvard, Ill., announces development of a four-purpose, all-steel hog pen which it claims will enable hog raisers to use a single hoghouse through the entire swine life cycle. Flexibility of use has been accomplished by eliminating the need for concrete curbs and by designing the pens with removable farrowing-crate rails and pen partitions. The basic hog pen is formed of panels standing approximately 37 in. high, with 5-in. spindle spacing in the upper section and 2½-in. spacing below. Panels

are available in any length to fit the job. A standard 24-in. gate is located in the center of the pen partition on the alley side. This center location of the gate makes it possible to convert the pen to a farrowing crate. It is said this pen is easily converted to a pig creep from the farrowing crate arrangement by removing the straining bar and the four rails on one side of the pen. Mangers and watering troughs for use in the pen are also available. By removing the remainder of the rails and the partition between pens, several of the pens can be opened up to increase the area needed for growing pigs or larger hogs. The absence of curbs and the all-steel construction, it is claimed, simplify cleaning and disinfecting of these pens.

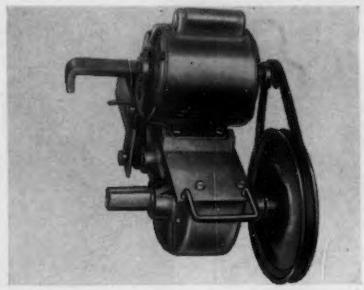
Bulk Feed Dust Collector

Ripco Air Systems, Oxford, Pa., announces a new compact dust collector to be used with their pneumatic bulk-loading and unloading systems. Designed primarily for use when unloading bulk feed into open bins, hog feeders and the like, the dust col-

lector through a swirling action separates air from the grain, dropping the grain by gravity and allowing the dust-free air to escape through the opening in the top. Compact in size, and measuring 14 in. in diameter and 16 in. deep, the collector can be carried in a truck on all trips, ready for use when needed.

Portable Transmission Unit

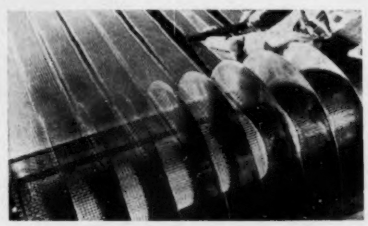
Calhoun Mfg. Co., Cedar Falls, Iowa, announces a portable transmission unit for use on false endgate or chain web wagon boxes. It has a 120-to-1 gear ratio and



weighs 62 lb. It is equipped with carrying handles for transfer from one wagon box to another. It can be used with any unloading mechanism and may be driven by a ¼ or ⅓ hp electric motor or a gasoline engine.

Braid Weave for Wire Cloth

Reynolds Wire Div., National-Standard Co., Dixon, Ill., announces it has developed an integral flat braid for weaving into wire cloth thereby providing a firm, workable edge. It is claimed that the strengthened edge of the wire cloth can be gripped, imbedded or otherwise fastened by methods previously impractical with wire cloth. It



is also said that safety from injury due to the sharp ends of cross wires is improved. The braid weave is available in 2-mesh to 8-mesh hot-dip galvanized wire cloth. It is woven up to 48 inches wide, and may be slit from 2 to 12 inches wide. The braid weave is made by including a flat braid as a warp (lengthwise) wire. After weaving, the wire cloth is hot-dip galvanized and then is slit through the braid to the reinforced edge. Cross wires are held firmly in place and the edge of the slit cloth is structurally strengthened by the braid.

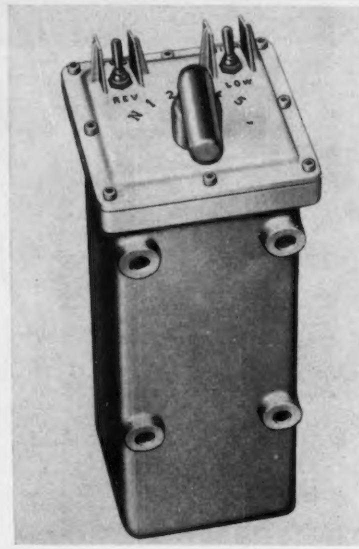
Flexible Metal Tubing

The International Metal Hose Co., Bellevue, Ohio, announces three grades of flexible metal tubing in an enlarged range of sizes and materials. This tubing is made with interlocked construction of strip metal in a choice of thicknesses from 0.010 to

0.034 in. and is available in galvanized, cold rolled and stainless steel, and bronze. Various weights and metals are available for applications as dust and fume collectors, suction and blower hose, blow-pipe and ventilating systems, agricultural dusters and fog sprayers, etc.

Finger-Tip Transmission Control

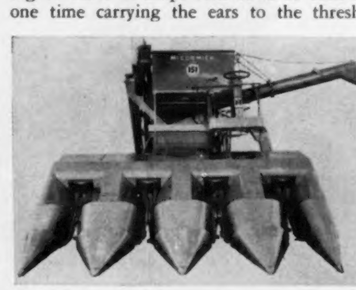
Caterpillar Tractor Co., Peoria, Ill., announces a new finger-tip transmission control for its DW20 and DW21 tractors, now available as optional equipment. A prime advantage of the new control, claimed by the manufacturer, is that it permits operators to shift up or down instantly by merely dialing a desired gear range, which eliminates the necessity of performing the usual



gear-shifting operations required by standard direct-drive transmissions. The new device is controlled by a gear selector located to the right of the operator at arm level. Mounted on top of the control box, it replaces the gear-shift lever. The standard clutch foot pedal is retained for use only when the machine is started from a standstill. This new system was originated and designed expressly to meet the demands of heavy earth-moving service.

Four-Row Corn Head

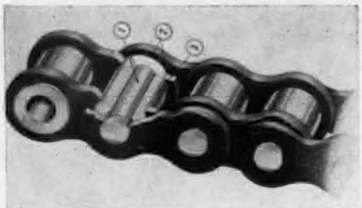
International Harvester Co., 180 N. Michigan Avenue, Chicago 1, Ill., announces a new big-capacity four-row corn head for use on its McCormick No. 151 combine. This new corn head is a mechanical device that adapts a combine for the picking and shelling of corn. It snaps four rows of corn at one time carrying the ears to the thresh-



ing cylinder of the combine where the kernels are shelled from the cobs. This corn head, presently on a limited preproduction basis, features a deep, low-angle design, which can pick four rows of corn simultaneously at spacings of 38, 40 or 42 in. It is claimed that long gathering points assure positive feeding of leaning and down stalks to star-type snapping rolls.

Oil-Impregnated Chain Bushings

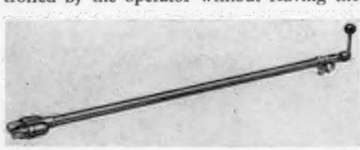
Whitney Chain Co., subsidiary of Foote Bros. Gear & Machine Corp., 303 West Hamilton Street, Hartford 2, Connecticut, announces that, as a development of the company's research, it is offering oil-impregnated, sintered steel bushings that are claimed to provide lifetime lubrication for the company's chain products. It is claimed that this development solves the basic chain problem, namely, that more damage is ordinarily caused by faulty chain lubrication than by years of normal service. It is claimed that this development assures complete built-in lubrication at all three critical



chain lubrication areas, namely, (1) pin, (2) plates, and (3) sprocket engagement. In operation, pressure and heat cause the built-in lubricant to expand and flow from the bushings, thereby providing a constant supply of lubricant to every working part of the chain. When operation of the equipment stops, the bushings reabsorb the oil, thereby assuring a permanent supply for the life of the chain. All essential dimensions of Whitney standard and extended-pitch chain conform to ASA standards, thereby simplifying specification for new equipment or as a replacement for existing drives.

Spray Jet for Broadcast Spraying

Spraying Systems Co., 3226 Randolph St., Bellwood, Ill., announces a new direction jet for broadcast spraying which combines spray nozzle and control valve in one assembly for spray selection without leaving the tractor seat. With this new jet the wide swath spray required in broadcast spraying may now be controlled, says the manufacturer, and varied to meet wind and field conditions without leaving the tractor seat. The jet is designed with a control valve that provides spray to either the left or right side of the tractor, or to both sides at one time, as well as on-and-off control. The entire desired sequence of operations can be controlled by the operator without leaving the



tractor seat. Since the spray can be shut off to either right or left, it can be set in the down-wind direction on windy days. This control feature is also of advantage when spraying near fence rows or buildings. The jet is easily mounted on a tractor with the control handle positioned convenient to the operator. The operator has complete control of the spray and may select type of spray and control shut-off in any desired way. The jet provides a choice of 5 different capacity ranges. The valve assembly is made of aluminum and stainless steel with nylon packings for maximum resistance to chemicals. Application of this new unit includes the broadcast spraying of grains and grasses and the spraying of liquid fertilizers, whereas the accuracy of a spray boom is not required.

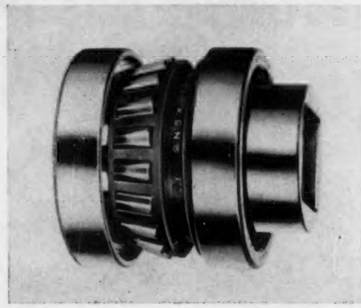
(Continued on page 562)

. . . New Products

(Continued from page 561)

Square-Hole Tapered Bearing

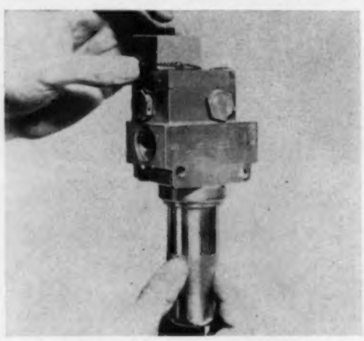
The Timken Roller Bearing Co., Canton 6, Ohio, announces development of a new square-hole tapered roller bearing that has been engineered for the rugged use on a disk harrow. The disks are mounted on a square axle which in turn is supported by square-hole bearings thus assuring a positive lock against rotation of the inner bearing race on the axle as well as positive locking of the disks. The disks thus locked turn freely and truly with each rotation of the axle. The square bore simplifies mounting or assembly and disassembly, since the bearing can be mounted directly on the square axle. Since the bearings are fitted with limited clearance the axle is free to



deflect slightly to compensate for heavy shock loads on the disk assemblies. Square-hole spools, which act as spacers between the disks, are likewise positively locked against rotation. By eliminating rotation of both the bearing and the spools on the axle, friction and wear between the bearing ends and the spool is eliminated. A tight fit between bearing, disks, and spacer spools can be maintained. Lubrication twice a year, at the beginning and end of each season, is all that is required. Another important feature of this bearing application is the extended cone which has a hardened smooth ground surface, which enables the grease seals to operate at maximum efficiency in keeping dust and dirt out, lubricant in, and maintenance down.

Mechanical Indicator Filters

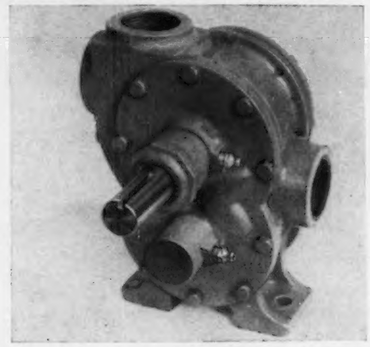
Purolator Products, Inc., Rahway, N. J., announces a new mechanical indicator with high or low-flow filters to provide a differential-pressure signal when cleaning is required. The new filters are adaptable to



any fluid system in which differential pressure can be used for measurement; they are capable of withstanding full-line pressure (4500 psi) and are operable under extreme temperature conditions. The filters employ a non-magnetic, pressure-sensitive piston which, when actuated by changes in differential pressure across the filtering element, transmits linear motion to an indicating mechanism which releases a visual button. Manual reset is accomplished simply by depressing the indicator button until it automatically engages the detent, and remains in a hidden position. Depending on the filtering media used, the degree of filtration for the new indicator filters ranges from 5 to 50 microns.

Farm Utility Pump

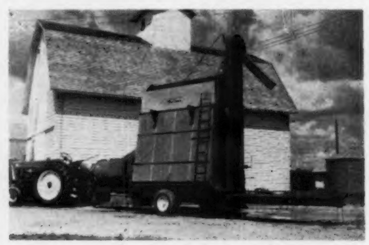
Goulds Pumps, Inc., 61 Black Brook Rd., Seneca Falls, N. Y., announces that it has developed a lightweight general farm utility pump which operates from a tractor power take-off drive and is specially useful for small irrigation projects, tobacco seed irrigation, and low-pressure liquid-fertilizer applications. Designated Figure 1956, the



pump has a pumping capacity of 10 gpm at 100 rpm, although the pumping capacity will increase in the same ratio as the speed. For maximum effectiveness, it should not be operated under 200 rpm except when pumping thick, viscous liquids. Maximum discharge head is 100 feet which is equivalent to 43 lb discharge pressure. It is completely portable since it weighs only 36 lb.

Crop Driers

The Oliver Corp., 400 W. Madison St., Chicago 6, Ill., announces the addition to its farm machinery line of two sizes of recirculating crop driers to provide more flexibility in preparing grain for early marketing or storage. The smaller machine has recirculating sections holding 300 bushels while the larger machine has 600-bushel capacity. The smaller machine has four



recirculating bins while the larger machine has eight. Each bin has 75 bushels capacity and the number can be varied according to need. A movable canvas closure with garner bin divider facilitates drying of small quantities. Heat for the drying operation is supplied by LP-gas burners ranging from 50,000 to 4,000,000 btu output, operating at all temperatures from zero F. Heat intensity is self-adjusting and is regulated by safety controls that are said to prevent accumulation of pockets of wet or scorched grain, to

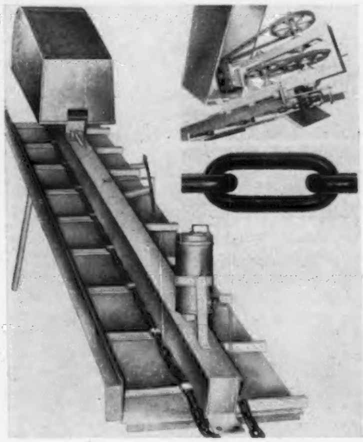
Crawler Tractor Catalog

Variable-Speed Pulleys

save fuel and to protect grain quality. Tractor power-take-off power circulates the grain from the bottom to the top of the bins, while an air cleaner removes dust and trash in this process. The metering rolls provide uniform and positive recirculating rates. Both driers, the larger weighing 7,583 lb and the other 5,219 lb, are portable.

Chain-Type Gutter Cleaner

H. D. Hudson Mfg. Co., 589 E. Illinois St., Chicago 11, Ill., announces a new chain-type gutter cleaner for dairy barns. Known as the "Hercules," this cleaner features self-aligning ball bearings on all shafts in the power transmission unit. Other features of the unit are roller-chain drive on reduction gears, special alloy sprockets and pulleys, and heavy welded channel-steel frame. The unit is protected from the weather by a deep-skirted galvanized steel hood. The bed and sideboard of the elevator are formed



from a single piece of extra-heavy galvanized steel to increase strength and maintain true alignment. The width of the "loaded" side of the elevator is adjustable to any gutter width by merely adjusting the center beam on the bed. The basic elevator is 8 ft long but can be extended with standard 4 or 8-ft sections. The chain is a special analysis heat-treated steel, oversize ⅜ inch in diameter. Flights are 2-inch high carbon steel angle. All parts of the cleaner are standard and can be adapted to almost any barn. It fits 14, 16 or 18-inch-wide gutters.

Sliding Ridge Cap

Aluminum Company of America, 1501 Alcoa Building, Pittsburgh 19, Pa., announces development of an aluminum sliding ridge cap designed for easy alignment and fast installation of its aluminum roof-

ing sheet. It is claimed the two-piece cap eliminates alignment problems common to the use of one-piece ridge caps. It is said to adjust easily to align with aluminum roofing sheets on both sides of the roof. The cap is embossed with the same pattern featured on the company's roofing sheet.

Machine Protection

Herculite Protective Fabrics, 125 Sussex Ave., Newark 3, N. J., announces that it has developed a new vinyl-coated nylon fabric for protecting machinery from early morning frost and other weather damage. Developed primarily to prevent forming of frost on aircraft parts, the company is developing the possibilities of this product for other applications, including farm equipment. The product is a specially developed vinyl-coated nylon fabric to which ice and snow will not adhere, nor will it stiffen or crack under cold-weather conditions. Weighing only 6 ounces per square yard, this product is lightweight, extra strong and water and shrinkproof. Another feature of this product is that covers made from it need not be dried before storing, as it is not subject to mildew or rotting.

Plastic Tile Layers

A tractor-pulled device which will form and lay heavy gage vinyl plastic drainage conduit to depths up to 30 in. is now in advance stages of development, according to an announcement by cooperators in the project.

The device is being developed jointly by Caterpillar Tractor Co., Union Carbide Plastics Co., Division of Union Carbide Corporation, Rome Plow Co., and the Agricultural Research Service of the U.S. Department of Agriculture.

The machine opens the soil and forms the plastic into a circular tube form, underground. Recent field tests in California indicated that the machine may be expected to lay more than 1,000 ft of conduit per hour. Test installations are being closely followed to determine performance.

MANUFACTURERS' LITERATURE

Literature listed below may be obtained by writing the manufacturer.

Hydraulic Hose and Tube Bulletins

Eastman Mfg. Co., Manitowoc, Wis. — Eastman technical bulletin No. 100 describes *medium* pressure hydraulic hose and tube assemblies. Copies are available for distribution. The bulletin contains 36 pages devoted to exclusive Eastman features found in medium to low-pressure Eastman hydraulic hose and tube assemblies, with accurate dimensional drawings and complete tables of available sizes. Also available is the company's technical bulletin 200 on *high* pressure assemblies. Copies of both bulletins are available on request.

Crawler Tractor Catalog

J. I. Case Co., Utility Sales Div., Racine, Wis. — A 2-color, 4-page catalog covering heavy-duty attachments to expand the work capacity of the company's utility crawler tractors. It features also direct-mounted tools for crawler-loaders, bulldozers, and drawbar tractors. Also described and illustrated is a flexible 3-point hitch power take-off for operating a variety of allied and agricultural-type attachments.

Spotweld Fasteners

The Ohio Nut and Bolt Co., 33 First Ave., Berea, Ohio — A new brochure, bulletin 595, gives complete information on parts for spot welding. In addition to complete dimensional information, the bulletin illustrates typical applications for spotweld fasteners and gives complete welding recommendations for all parts to the most popular metal thicknesses.

Variable-Speed Pulleys

T. B. Wood's Sons Co., Chambersburg, Pa. — A 12-page bulletin giving technical data on the company's line of "MS" variable-speed pulleys designed to eliminate freezing and sticking. The bulletin gives technical data for five sheaves designed for ratings of 2, 3, 5, 10 and 15 hp.

Variable-Speed Drive Bulletin

Sterling Electric Motors, Inc., 5401 Telegraph Rd., Los Angeles 22, Calif., announces publication of bulletin No. 195 describing its new variable-speed drive. Detailed information on the company's remote controls is included.

Hay-Conditioning Booklet

International Harvester Co., Consumers Relations Dept., 180 N. Michigan Ave., Chicago 1, Ill. — A 20-page booklet (CR-1294-I) describing how hay conditioning cuts curing time and boosts feeding value. Charts and photographs illustrate how accredited tests held throughout the country prove that conditioned hay dries faster.

Gas Turbine Engine

Curtiss-Wright Corp., Santa Barbara Div., Att. Customer Relations, P.O. Box 689, Santa Barbara, Calif. — A catalog sheet describes the company's lightweight, miniature gas turbine engine which can be used as an auxiliary power unit, a portable pumping system, or a portable pneumatic system source.

Motor Scraper Bulletin

Allis-Chalmers Mfg. Co., Construction Machinery Div., Milwaukee 1, Wis. — A 16-page catalog giving engineering features of the company's TS-260 motor scraper powered by the company's 16000 diesel engine developing 230 hp. It includes pictures of the scraper, its power plant, etc., and also information on the A-C 20-ton rear dump wagon and specifications of both wagon and motor scraper.

Asphalt Liners

W. R. Meadows, Inc., 2-18 Kimball St., Elgin, Ill. — A 30-page book describing the company's prefabricated asphalt mats or panels under the trade name "Hydromat," which have a wide variety of uses for the control and conservation of water, for the containment of liquids, including unlined farm ponds, irrigation ditches, etc.

Nickel Casting Alloys Booklet

International Nickel Co., Inc., 67 Wall St., New York 5, N. Y. — A 27-page booklet intended as a compact guide to the major nickel-containing casting alloys, including condensed, informative data on the range of properties offered, industries served, and general applications for each of the alloys included.

Pyrotex Parts Booklet

Raybestos-Manhattan Corp., Equipment Sales Div., Bridgeport, Conn. — A 12-page bulletin on the physical properties and application of Pyrotex, the company's asbestos-reinforced, thermosetting phenolic resin plastic. Descriptions of this product to various fields of application are included.

LP Gas

Marvel-Schebler, Century Products Div., Borg-Warner Corp., Decatur, Ill. — A 24-page booklet "LPG Motor Fuel and You," containing factual information and illustrations of complete LP motor fuel systems, conversion instructions, compression tests, cold manifold operation, installation instructions and electric-circuit wiring. Complete data on the safety, economy and availability of LP-gas is included.

Fertility Investigations on the Black Earth Wheatlands of the Darling Downs, Queensland, by S. A. Waring, W. E. Fox, and L. J. H. Teakle.

Lighting the Farm Buildings, by D. P. Brown, D. E. Wiant, and R. L. Maddex. Circular 734, June 1958. Cooperative Extension Service, Michigan State University, East Lansing, Mich.

Fluid Milk Plants in the Southeast, by James C. Taylor and Ralph W. Brown. Marketing Research Report No. 232, 1958. Price, 30 cents. Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

Annales de L'Institut National de la Recherche Agronomique, Serie A, Annales Agronomiques. 146-page booklet, January-February, 1958. Summaries in English are given. Institut National De La Recherche Agronomique, 7, rue Keppler, Paris, France.

Progress Report, 1953-1957, Experimental Farm, Fredericton, New Brunswick. Catalog No. A56-41, 1957. Experimental Farms Service, Canada Department of Agriculture, Ottawa, Ontario, Canada.

The following articles are reprinted from the Quarterly Bulletin, Michigan Agricultural Experiment Station, Michigan State University, East Lansing, Vol. 41, No. 4, May 1959: *The Use of a Recording Resistance Bridge in Soil Moisture Studies* (Article 41-79, pages 768 to 777), by L. H. Stolzy, G. A. Crabb, Jr. and A. E. Erickson; *Cost of Michigan Fruit Storage Buildings as Affected by Size and Type of Construction* (Atricle 41-80, pages 779 to 790), by I. J. Pflug and M. W. Brandt; *Soil and Air Temperature as Affected by Polyethylene Film Mulches* (Article 41-86, pages 834 to 842), by Shigemi Honma, Frank McArdle, John Carew and D. H. Dewey; and *Labor Requirements for Herringbone and Other Milking Systems* (Article 41-96, pages 905 to 921), by B. A. Brown, W. W. Snyder, C. R. Hoglund and J. S. Boyd.

Proceedings of the First Intersociety Conference on Irrigation and Drainage, cosponsored by the American Society of Agricultural Engineers, the American Society of Civil Engineers, and the Soil Science Society of America, in cooperation with the U. S. National Committee, International Commission on Irrigation and Drainage. 134 pages. Price, $4.50. U. S. National Committee, International Commission on Irrigation and Drainage, P.O. Box 7826, Denver 15, Colo.

Application of Newton's Equation to Moisture Removal from Shelled Corn at 40-140° F, by C. W. Hall and J. H. Rodriguez-Arias. Reprinted from the Journal of Agricultural Engineering Research, Vol. 3, No. 4, pages 275 to 280, 1958. Carl W. Hall, Agricultural Engineering Dept., Michigan State University, East Lansing, Mich.

Tractor Operation and Daily Care. 112 pages. Price, $2.00. Southern Association of Agricultural Engineering and Vocational Agriculture, Barrow Hall, Athens, Ga.

Reports on tests of *Ransome FR-THR 1006 Disc Harrow* (No. 203); *"Saflex" P.T.O. Safety Guard* (No. 204); *"Hanover" Disc Harrow* (No. 205); and *Wilder "Multi-Masta" Forage Harvester/Scrub Cutter* (No. 208). *Agricultural and Horticultural Engineering Abstracts, Vol. X, No. 2, 1959.* Abstracts 439 to 918. The British Society for Research in Agricultural Engineering, National Institute of Agricultural Engineering, Wrest Park, Silsoe, Bedfordshire, England.

Thirty-Fourth Annual Report of the Kansas Committee on the Relation of Electricity to Agriculture. December 1958. Agricultural Engineering Dept., Kansas State College, Manhattan, Kans.

Report of Research in Progress in Agricultural Engineering During 1957-58, by C. V. Paul and E. C. Peter. Reprinted from the Allahabad Farmer, Vol. XXXII, No. 6, November 1958. C. V. Paul, Head, Agricultural Engineering Dept., Allahabad Agricultural Institute, Allahabad, U. P., India.

Harvesting Blueberries Mechanically, by Scott Hedden, H. P. Gaston and J. H. Levin. Article 42-2. Reprinted from the Quarterly Bulletin, Vol. 42, No. 1, pages 24 to 34, August 1959. Michigan Agricultural Experiment Station, Michigan State University, East Lansing, Mich.

Mechanization of Citrus Fruit Picking, by J. P. Jutras and G. E. Coppock. Reprinted from the Proceedings of the Florida State Horticultural Society, Vol. 71. October 1958. Florida Citrus Experiment Station, University of Florida, Lake Alfred, Fla.

RESEARCH NOTES

Brief news notes and reports on research activities of special agricultural-engineering interest are invited for publication under this heading. These may include announcements of new projects, concise progress reports giving new and timely data, etc. Address: Editor, AGRICULTURAL ENGINEERING, St. Joseph, Michigan.

New Book on Farm Buildings

Wallace Ashby, J. R. Dodge, and C. K. Shedd have written a non-technical book, "Modern Farm Buildings," published by Prentice-Hall, Inc. See "New Books" column. Mr. Ashby is head of the Livestock Engineering and Farm Structures Research Branch of the Agricultural Engineering Research Division of USDA's Agricultural Research Service. Mr. Dodge and Mr. Shedd were members of the research branch of AERD.

New Project on Farmstead Water Requirements

A new cooperative project on farmstead water requirements has been established by USDA and the University of Maryland. Data will be obtained on the significant domestic uses of water on farmsteads. This will include volumes, pressures, rates of flow, peaks, temperature, and use patterns. The information will guide farmers, extension workers, equipment manufacturers, and others in water-system planning.

William A. Bailey of the Livestock Engineering and Farm Structures Research Branch of the Agricultural Engineering Research Division of USDA's Agricultural Research Service, and George J. Burkhardt, of the university's agricultural engineering department will conduct the research.

USDA Engineer Modifies Inverter for Electric Insect Traps

J. P. Hollingsworth, USDA engineer, has modified a commercial inverter for converting d.c. from storage batteries to a.c. to operate electric traps used in insect surveys when 110-volt electric service is not available.

The modified inverter will be particularly useful for operating survey traps in remote areas of Arizona, Nevada, California, and northwestern Mexico. More than 170 electric traps, using argon-glow lamps as the attractant, were placed in operation in 1958 by USDA's Plant Pest Control Division. This was done to detect the pink bollworm moth, following discovery of a new infestation of the pest southwest of Phoenix, Ariz., in July 1958.

Design of these traps and discovery of the wavelength of ultraviolet light that attracts the pink bollworm moth were established by earlier cooperative research in Texas by Mr. Hollingsworth and C. P. Briggs, also a USDA engineer, working with entomologists concerned with cotton insects.

Mr. Hollingsworth and Mr. Briggs are in the Farm Electrification Research Branch of the Agricultural Engineering Research Division of USDA's Agricultural Research Service. Their headquarters are at the Texas Agricultural Experiment Station, College Station.

Recent Publications Available

Three recent technical publications of USDA's Agricultural Research Service and two popular Alabama-ARS circulars of interest to agricultural engineers are available. The titles are: Suction Reclaimer for Shattered Seed (ARS 42-24) by Leonard M. Klein and Jesse E. Harmond, Mechanical Seed Cutting and Handling of Potatoes (ARS 42-21) by George W. French, Ginning Acala Cottons in the Southwest (ARS Production Research Report No. 27) by Walter E. Chapman, Jr., and Victor L. Stedronsky, Mechanized Cotton Production in Alabama (Circular 127) by T. E. Corley of ARS and the Alabama Agricultural Experiment Station, and C. M. Stokes and F. A. Kummer of the Alabama station, and Using Low-Volume Farm Sprayers (Circular 126) by Mr. Corley.

ARS 42-24, ARS 42-21, and ARS Production Research Report No. 27 may be obtained from the Information Division, Agricultural Research Service, U.S. Department of Agriculture, Washington 25, D. C. Circulars 126 and 127 are available at the Alabama Agricultural Experiment Station, Auburn.

New Miscellaneous Publications Available

Five new USDA Miscellaneous Publications that describe building plans available through the Cooperative Farm Building Plan Exchange have been printed, bringing the total number of plans to 36.

The new publications are: Fence-Line Cattle Feeders (M.P. 789), Home-Made Milking Stalls (M.P. 790), Breeding Rack (M.P. 791), Variable-Width Chute (M.P. 792), and Screen Chamber for Dairy Barn Flushings (M.P. 793).

The new publications may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D. C., for 5 cents each.

Grass Seeding Aided by Plastic Covers

Grass seedings on certain sites—including earth dams, waterways, terrace channels and ridges, and lawns—in the semi-arid Southwest can be started easier if polyethylene sheets cover new plantings the first few days to keep moisture in the upper one-half inch of soil.

Dr. Thomas J. Army, soil scientist, and Elmer B. Hudspeth, Jr., agricultural engineer, both of USDA's Agricultural Research Service, obtained 65 percent emergence of Blackwell switchgrass in seedings covered by clear plastic sheets, removed seven days after planting. Similar emergence was obtained under black plastic, but the plants were abnormal due to lack of light. Seedings failed completely in plots not covered with the polyethylene sheets.

The researchers, working in cooperation with the Texas Agricultural Experiment Station, found that the covers aid especially in starting urgently needed grass seedings of limited size in medium to fine-textured "hardland" soil of the Texas Panhandle and adjacent states. Rapid drying and surface crusting that occur on some 12 million acres of soil in that area often cause new grass seedings to fail.

Best times to use the covers are fall and early spring, when warm, moist "greenhouse" conditions created are ideal for maximum grass emergence. High temperatures that develop under the covers in summer will kill grass seedings. Ample moisture in the seed zone is necessary before the covers are fastened down, but no more should be needed, if the covers are properly secured, until they are removed.

About 60 Attend Cotton Ginning Conference

About 60 representatives of the National Cotton Council, federal agencies, state universities, and industry research and development departments attended the annual USDA Cotton Ginning Work Planning Conference at Clemson, S. C., June 7, to discuss cotton ginning research.

New Developments in Fruit Harvesting and Handling in the Pacific Northwest, by S. W. McBirney, agricultural engineer, AERD, ARS, USDA, Wenatchee, Wash. Paper presented at the Annual Meeting of ASAE at Cornell University, Ithaca, N. Y., June 1959, on a program arranged by the Power and Machinery Division. Paper No. **59-117.**

The author discusses the major new developments in fruit harvesting in the Pacific Northwest, including the rapid adoption of bulk bin handling of apples and pears, the two largest fruit crops, and the use of straddle carriers for hauling fruit and empty containers between orchard and warehouse. He also explains the limited commercial use of self-propelled machines with elevating platforms for use on ladder operations, such as picking, thinning, and pruning. It is also stated in the paper that studies are in progress on methods of combining labor saving principles which should further reduce the cost of fruit harvest, and also that mechanization methods are being studied for new, prepared types of orchards, such as hedgerow plantings of dwarf trees.

Effect on Relative Humidity When Drying Air Is Heated by Combustible Fuels, by G. M. Petersen, associate professor of agricultural engineering, University of Nebraska, Lincoln. Paper presented at the Annual Meeting of ASAE at Cornell University, Ithaca, N.Y., June 1959, on a program arranged by the Electric Power and Processing Division. Paper No. **59-312.**

This paper presents four special charts prepared to simplify the determination of changes in relative humidity to be expected when air is heated. The charts may also be used to determine the change in temperature required to produce any desired change in relative humidity. One chart is for any method of heating which adds nothing but heat to the air. Other charts are for the three special cases of heating air by direct combustion of natural gas, of L-P gas, and of gasoline or fuel oil, with all products of combustion going into the air being heated. Tables prepared in conjunction with the charts show, for the same heating methods and a range of air temperatures, specific heat requirements and the heating rate required to produce a one degree change in a one cfm air flow.

A New Analysis of Batch Grain Dryer Performance, by G. L. Nelson, professor of agricultural engineering, Oklahoma State University, Stillwater. Paper presented at the Annual Meeting of ASAE at Cornell University, Ithaca, N. Y., June 1959, on a program arranged by the Farm Structures Division. Paper No. **59-415.**

The theory of similitude and dimensional analysis as applied to data from experiments on drying grain, principally wheat and grain sorghum, with forced circulation of air, is discussed in this paper. The development of dimensionless parameters or Pi terms, to include the design and operating variables thought to be pertinent to the performance of a grain drying system with a batch of uniform depth and rate of air circulation, is explained by the author. He also states that these parameters were evaluated for the experimental data and that a generalized equation was then developed to include these parameters and to fit the values from experiments. The prediction equation can be used to compute average batch drying rates, instantaneous drying rates, and drying rates at different depths in the batch, according to the author. A basis is also presented for designing experiments on grain drying using scaled down or model batch dryers to predict performance of prototype installations.

Solving Water Quality Problems on the Farm, by George H. Klumb, technical director, Culligan, Inc. Paper presented at the Winter Meeting of ASAE in Chicago, December 1958, on a program arranged by the Soil and Water Division. Paper No. **58-802.**

The author states that impurities found in farm water supplies can cause many problems on the farm and in the farm home, and that they can be removed and water quality problems can be effectively controlled by the use of water conditioning equipment. This paper lists the water quality problems on the farm as caused by: (1) Hardness caused by calcium and magnesium which wastes soaps, synthetic detergents, and compounds used in dishwashing and dairy farm cleaning. The solution given for this problem is the use of water softening equipment; (2) iron and manganese which cause rusty or brownish-black stains on porcelain, plumbing fixtures, dishes and fabrics and ruin the good flavor of coffee, tea and other beverages. Oxidation and filtration, or, in some cases water softening, is advised by the author to remove iron and

manganese; (3) hydrogen sulfide, a gas dissolved in water, which has an offensive "rotten egg" odor, tarnishes silverware, corrodes pipes, and stains clothing and plumbing fixtures. It is stated in the article that this problem can be solved by oxidation and filtration; (4) acid water which rusts pipes and produces staining. This condition can be corrected by neutralizing the acid, according to the author; (5) contamination of water by disease-producing organisms, which makes the water unsafe to drink. This article states that contamination can be controlled by disinfection using a chlorinator; (6) turbid or cloudy water which is caused by the presence of small particles of mud or clay and makes the water unacceptable for household and dairy farm use. It is advised in the paper that this cloudiness can be removed by filtration; (7) taste and odor produced by growth and subsequent decomposition of tiny plants called algae in surface water supplies. Treating the water in the farm pond or reservoir is the solution given for this problem; (8) color produced by tannins and related impurities which can be removed by chlorination, coagulation and filtration.

Cost and Return Analysis of Crop Production Machinery Size, by D. A. Link and K. K. Barnes, respectively, graduate asst. and professor of agr. eng., Iowa State College, Ames. Paper presented at the Annual Meeting of ASAE at Cornell University, Ithaca, N. Y., June 1959, at a program arranged by the Power and Machinery Division. Paper No. **59-127.**

This paper reports a body of theory which attempts to account for the trends in farm machinery size, and states that the basic approach to the problem is economic. According to the authors the machine is considered as an object into which the owner puts money, and out of which he gets a useful service, and the optimum-size machine is assumed to be the one which maximizes the profit from the crop on which the machine is used. In this paper, profit is defined as gross revenue (R) minus total cost (C). Both R and C are functions of the widths of all the machines used in the production of the crop. By estimating the losses that result from untimeliness of operation, R is written as a function of the width (W) of each of the machines used on the crop. Cost is also found as a function of W by estimating the effect of W on each individual item of cost of ownership and operation. Then both R and C are differentiated with respect to W and set equal to each other. Solving the resulting equation for W gives an expression for maximum profit width. Two specific cases are considered: (1) The widths of all the machines used on a crop are independent; (2) The widths are not independent. An example is also given to demonstrate the use of the theory.

Evaluating Flood Damage Reductions from Proposed Works of Improvement, by Frank P. Erichsen, hydraulic engr., Soil Conservation Service, USDA, Milwaukee, Wis. Paper presented at the Annual Meeting of ASAE at Cornell University, Ithaca, N. Y., June 1959, on a program arranged jointly by the Soil and Water Division and the Public Lands and Public Works group. Paper No. **59-205.**

This article deals with evaluating flood damage reductions from proposed works of improvement under the Public Law 566 watershed protection and flood prevention program. Types of damage include such items as floodwater, erosion, and sediment damage. Program formulation is discussed, and benefit appraisal procedures are presented.

NEW BOOKS

Grasslands. Edited by Howard B. Sprague. Cloth. 6 x 9½ in. xv+406 pages. Illustrated and indexed. Copies can be obtained from the American Association for the Advancement of Science, 1515 Massachusetts Ave., N.W., Washington 5, D.C. $9.00.

This volume includes the papers presented at the eight symposium sessions on grasslands at the New York Meeting of the AAAS in December 1956, and is designated as Publication No. 53. Sessions consisted of papers on specific areas of subject matter, in which the authors were invited to present a review of the current development of grasslands. Subjects, which are included in the book's eight chapters, are on: Sciences in support of grassland research; forage production in temperate humid regions; engineering aspects of grassland agriculture; forage utilization and related animal nutrition problems; evaluation of the nutritive significance of forages; grassland climatology; ecology of grasslands; and range management. A list of contributors is included at the front of the book, as well as a list of references at the end of each chapter. Although some areas of knowledge affecting grasslands are not represented in the selected papers published in the book, this volume should prove helpful to scientists who are desirous of keeping abreast of progress on the broad front of grasslands research, beyond the field of their own specialization.

Getting Started in Irrigation Farming, by Roger W. Dugger. Paper. 8 x 11 in. 62 pages. Illustrated. Published by The Interstate Printers & Publishers, Inc., Danville, Ill. $1.25.

This laboratory text is designed to meet the needs of professional agricultural workers who are charged with the responsibility of teaching adult farmers and high-school students about getting started in irrigation farming. The following topics are discussed: Soil to irrigate; crops to irrigate; water for irrigation; amounts of water needed for irrigation; well water; well pumps; surface water; pumping power units; surface irrigation; sprinkler irrigation; economics of irrigation; and terms and equivalents. Along with a generously provided work space is a list of selected references. An added supplement is a 4-page list of suggestions for teachers.

Ground Water Hydrology, by David K. Todd. Cloth. 6 x 9½ in. xii+336 pages. Illustrated and indexed. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y. $10.75.

This book presents a unified, comprehensive account of the fundamentals and recent methods and problems encountered in the field of ground water hydrology and reports on the future role of ground water as a major water supply source in the United States. It deals with such problems as: Locating a ground water supply, constructing a well, and determining how much water it will yield; determining the amount of water that can be pumped from wells located near each other or near streams; dangers of pollution of ground water, whether it be from sewage, brines, industrial wastes, or from nuclear power plants; and control of sea water in wells near the coast.

Modern Farm Buildings, by Wallace Ashby, J. R. Dodge, and C. K. Shedd. Cloth. 6 x 9 in. ix+390 pages. Illustrated and indexed. Published by Prentice-Hall, Inc., 70 Fifth Ave., New York 11, N. Y. $7.35.

In simple terms, three authorities on farm housing, present practical, helpful, up-to-date information about farm buildings that conforms to the latest recommendations of the U.S. Department of Agriculture. This book is compiled to help either the farmer, the builder or the designer of farm buildings to decide what kind of building will be most useful under a given set of requirements due to climate and type of farming throughout the United States. Some of the topics included in the book are: Types of crop storage buildings accompanied by the advantages and disadvantages of each type; descriptions of building for farm animals and poultry, plus the advantages and disadvantages of the different types of buildings under various climatic and farm conditions; general information about farm buildings; how to read drawings and make sketches; characteristics of good plans and how to obtain them; water supply; waste disposal; electric wiring, lighting, and heating; the various building materials, types of construction; and how to build.

Professional Engineers' Income and Salary Survey — 1958. Paper. 6 x 9 in. 51 pages. Copies are available at the National Society of Professional Engineers, 2029 K St., N.W., Washington 6, D.C. $2.00.

This report represents the findings of the fourth biennial national salary survey con-

ducted by the NSPE, and the respondents who provided the information are all members of the organization, which consists of individual professional engineers, all of whom are registered under the engineering registration laws of the individual states. The booklet contains four parts: How the survey was conducted; who were surveyed; how much did they learn in 1958; and trends since 1952. Also included are charts and an appendix tables, plus a copy of the questionnaire used in the survey. As the previous surveys have been, this 1958 report should be of value to engineering firms, industrial organizations, national engineering organizations, local and state governmental agencies, and the departments of the Federal Government, as well as the United States Congress.

Water Facts for the Nation's Future — Uses and Benefits of Hydrologic Data Programs, by W. B. Langbein and W. G. Hoyt. Published by The Ronald Press Co., 15 E. 26th St., New York 10, N. Y. $5.00.

Sponsored by the Conservation Foundation, this timely book evaluates existing federal and state hydrologic programs for collecting, interpreting, and publishing water data. It gives practical suggestions for future expansion and improvement, and outlines the specific steps which must be taken if these programs are to furnish the factual information indispensable to intelligent utilization of our water supplies.

1958 and 1959 Grassland Proceedings. Paper, 8½ x 11 in. 1958 Proceedings, 153 pages. 1959 Proceedings, 102 pages. A limited quantity of each publication is available at the American Grassland Council, P.O. Box 30, Norwich, N. Y. $2.50, plus 50¢ to cover postage and handling, for each copy.

The Grassland Proceedings is a compilation of papers presented at the Annual Program of The American Grassland Council. The 1958 grassland symposium was sponsored jointly with the American Dairy Science Association, and was held at North Carolina State College, Raleigh, in June 1958. Discussions on the following subjects are included: Effect of soil fertility upon the yield and nutritive value of forages; effect of growth stage, chemical composition and physical properties upon the nutritive value of forages; conditions influencing forage acceptability; evaluating on the basis of energy and an extension worker's viewpoint on evaluating the nutritive quality of forages; forage utilization in the west, mid-west, south, and east; economics of various methods of harvesting and utilizing forages; and can dairy cattle be bred for increased forage consumption and efficiency of utilization.

The grassland program of 1959 was sponsored jointly with The American Society of Range Management, and was held at Hotel Tulsa, Tulsa, Okla. Topics included in the program were on: Importance of grassland in our national life; new frontiers in range management; breeding superior forage plants for the great plains; establishing and reseeding grassland in the great plains and western corn belt; wildlife in relation to trends in range management; grassland improvement and the outlook for the deep south; measuring progress in grassland research for the north central states; grassland management problems; progress in harvesting and handling forage; importance of irrigated grasslands in animal production; the status of present knowledge on the utilization of harvested forages by livestock; automation and integration in the livestock industry; and performance breeding in beef cattle today.

(Continued on page 572)

. . . New Books

(Continued from page 571)

Water Inventory of the Cuyahoga and Chagrin River Basins, Ohio, Volumes 1 and 2. Vol. 1 (basic report): Paper; 8½ x 11½ in., 90 pages, including 31 maps, charts, and other illustrations. $2.75, plus tax. Vol. 2 (map atlas): Paper; 15 x 20 in., 32 pages, including 26 maps or charts. $3.25, plus tax. Copies are available from the Division of Water, Department of Natural Resources, 1562 W. First Ave., Columbus 12, Ohio.

This is the first in a series of 18 reports to inventory the water resources of Ohio, determine water problems and outline possible solutions to them. The study covers water uses, and projected needs, water availability and possible future sources, and problems of pollution, floods, erosion and recreation. In addition to the special maps included in these volumes is a list of other reports carrying pertinent technical information on the area, which should prove useful to county and municipal leaders, engineers, planning organizations, chambers of commerce, industries, agricultural groups, water agencies, universities, schools, and many others.

Fruit Key and Twig Key to Trees and Shrubs, by William M. Harlow. Paper 5¾ x 8½ in., 56 pages. Over 350 illustrations. Indexed. Published by Dover Publications, Inc., 180 Varick St., New York 14, N. Y. $1.25.

This book, combining the two keys in one volume, was prepared to provide botanists and outdoorsmen with a quick identity guide to any trees growing in Eastern North America.

1958 Book of ASTM Standards. Ten parts, 13,600 pages. Copies can be obtained from the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Each part is priced individually, depending on size. The complete set is $116.00.

The 1958 edition increased from 7 to 10 parts, and within these parts are contained 2,450 standard specifications, methods of tests, definitions of terms, and recommended practices. Each part is complete with a detailed subject index and a list of standards in numeric sequence, and to keep this book up to date, supplements will be issued to each part late in 1959 and 1960. Also, a complete index is furnished without charge with each set of the book of standards.

NEW FILM RELEASES

A Product of the Imagination. 26 min. Color and sound. Produced by Wilding Picture Productions, Inc. Organizations, desiring to borrow the movie, should write Motion Picture Section, Aluminum Company of America, 1501 Alcoa Building, Pittsburgh 19, Pa.

From mine to finished product, the camera reviews the 70-year-old aluminum industry's past, present, and future, in terms of processes, plants, and products. Viewers see how aluminum is forged, cast, rolled, drawn, extruded, and impacted, and also Alcoa's forecast of creations in aluminum design. The film is ideal for anyone from the subteen age group and beyond, according to Alcoa.

Modern Irrigation Equipment. 16 mm. 27 min. Color and sound. Price, $250. Rental $10.00 per day. For further information write to: Department of Visual Communication, University Extension, University of California, Los Angeles 24, Calif.

This film is designed to give information on various types of equipment available for modern irrigation methods in agriculture. It shows methods of ditch construction and lining, land preparation, water application, water distribution, and water measurement; also, a number of methods of preparing land for surface irrigation is seen in detail. Several different types of sprinkler systems are illustrated with a discussion of drainage methods. Also emphasized are the latest methods that have been developed to make irrigation more efficient, to conserve water, and to aid in increased agricultural production. University of California Extension advises that this movie represents a valuable educational aid for schools, organizations, and associations concerned with the aspect of modern irrigation equipment.

Marketing Research Pays Off. 16 mm. 13 min. Color and sound. Price, $62.85. **Prescribed Burning in the South.** 16 mm. 24 min. Color and sound. Price, $112.56. Released by the U.S. Department of Agriculture. For information regarding the public use of these or for a complete catalog of all agricultural films available write to the distributor, United World Films, Inc., Government Dept., 1445 Park Ave., New York 29, N. Y.

Marketing Research Pays Off presents the story of the Department's study of farm markets. USDA scientists are shown at work on projects to improve marketing methods, to reduce processing and handling costs and to expand markets for farm products.

Prescribed Burning in the South describes the objectives, planning, execution and benefits of prescribed burning in Southern pine coastal plain forests. The film is designed mainly for the training of foresters and fire suppression crews.

. . . News

(Continued from page 554)

ships are named for Ralph J. Bugbee, retired head of the CVPS Farm Department, who assisted Vermont farmers for many years in applying electricity to their farm problems, and is also an authority on farm ventilation problems. He is at the present time a consultant with the firm.

Additional High Lights of 52nd Annual Meeting

The following Student Honor Awards, Journal Paper Awards, and Blue Ribbon Awards for the 52nd Annual Meeting exhibits are in addition to the awards reported in the August issue.

Student Honor Awards

The Student Honor Awards are made to recognize outstanding scholarship attainments and general participation in student activities. Recipients are elected by their respective ASAE Student Branches. The award consists of a certificate and gold key. The following student branch members of ASAE were elected to receive the Award in 1959: D. C. Anderson, Kansas State University; Richard Appel, State College of Washington; J. E. Berney, Oregon State College; P. W. Bridge, University of Maine; A. M. Brown, Colorado State University; C. E. Dorgan, Kansas State University; Robert Fairless, Oklahoma State University; D. W. Fitzsimmons, University of Idaho; R. P. Gehman, Pennsylvania State University; M. L. Gerdes, University of Illinois; Larry Gutekunst, University of Missouri; C. F. Hankins, University of Arkansas; C. E. Hood, Jr., North Carolina State College; J. P. Hoskyn, University of Arkansas; S. D. Hunt, University of Florida; H. H. Klueter, University of Illinois; G. O. Lovig, Iowa State College; R. W. McCarley, Mississippi State University; H. W. McDonald, Jr., Louisiana Polytechnic Institute; R. L. Mensch, Iowa State College; J. W. Mickley, Pennsylvania State University; J. D. Pope, Oklahoma State University; Vincent Salomonson, Colorado State University; H. D. Schofield, University of Missouri; F. W. Schultz, University of Illinois; D. R. Smelcer, University of Idaho; W. L. Smith, University of Tennessee; H. M. Soule, University of Maine; Leslie Stone, State College of Washington; R. D. Stratton, Kansas State University; J. B. Uhl, Pennsylvania State University; Donald Werbach, Iowa State College; J. C. Willis, Mississippi State University; and H. M. Wilson, Jr., Virginia Polytechnic Institute.

Journal Paper Awards

The Journal Paper Awards are made to the authors of the five papers—published in the 1958 issues of AGRICULTURAL ENGINEERING — given the highest merit rating as reference literature by the Committee on Journal Paper Awards: B. L. Bondurant, chairman; J. E. Harmond, vice-chairman; L. G. Johnson, G. A. Karstens, T. O. Hodges, and V. H. Baker. For authors who are ASAE members, the award includes a certificate and one year's membership dues. Following are the recipients of the 1959 Awards: Walter Soehne for "Fundamentals of Pressure Distribution and Soil Compaction Under Tractor Tires" (May); K. H. Norris for "Measuring Light Transmittance Properties of Agricultural Commodities" (October); S. M. Henderson for "On-the-Farm Egg Processing: Part II — Moisture Loss" (January); C. W. Hall for "Theoretical Considerations in Materials Handling Systems" (September); and G. L. Nelson, G. W. A. Mahoney and J. I. Fryrear for "Stability of Poles under Tilting Moments: Part I—Experiments and Results" (March).

Blue Ribbon Awards for Annual Meeting Exhibits

Public service and industrial organizations from all parts of the country displayed exhibits at the 1959 Annual ASAE Meeting, with classifications including: Extension methods; publications; slides and film strips; radio and television; motion pictures; and demonstration models.

The blue ribbon winners for extension methods were: N. H. Wooding, Jr., Pennsylvania State University, on water purification equipment; C. S. Winkelblech, Cornell University, on selection of forage harvesting and handling equipment; R. G. Pfister, Michigan State University, on using TV to promote National Farm Safety Week; and E. O. Eaton, Cornell University, on 4-H lawn power equipment.

In the industrial periodicals class for publications, the winner was Portland Cement Association with its publication, "Rural Concrete Builder." The University of Massachusetts was the winner in the public agency periodical classification group for its periodical, "Agricultural Engineering." Winners in the industrial bulletins classification under publications included: J. D. Hallenberg, Westinghouse Electric Corp., for an idea book for 4-H electric program leaders; and I. W. Bigalow, U. S. Steel Corp., for a bulletin on loose housing. N. H. Wooding, Pennsylvania State University, with a bulletin on making your water supply safe; Donald Brown and D. E. Wiant, Michigan State University, with their bulletin on lighting your home; and C. L. Hill, Purdue University, with a bulletin on hay crushing, won ribbons in the public agency bulletins class.

In the slides and film strips category, S. W. McBirney, ARS, USDA, was a winner in the public agency division for "Harvesting and Handling Apples in Bulk Bins," as well as R. M. Ritchie, Jr., North Carolina State College, for "Hog Production Buildings." Successful Farming Magazine won with its entry of "Materials Handling Systems—for Profitable Farming" in industrial classification of slides and film strips.

Radio and television winners were: Don Brown, Michigan State University, on progress through agricultural engineering; and Allen Butchbaker, Michigan State University, on electricity at work.

Winners of the motion pictures awards in the public agency class were: Motion Picture Service, USDA for a movie on cotton —fiber with a future; Iowa State College for a motion picture on the self-feeding haymaker; Cornell University for its movie on corn on the furrow; and Iowa State College for one on operation feed bunk. In the industrial classification, Stran-Steel Corp. won a ribbon for its movie on the new look in modern farming, as did A. O. Smith Corp. for a motion picture on a sealed system for high moisture grain, and New Holland Machine Co. for one on how grass grows.

Public agency class winners for demonstration models included Robert Aldrich, Michigan State University, for a demonstration on dairy housing layout and John Layer, Cornell University, whose demonstration was on potato storage proportioning ventilation controls. Ivan Bigalow, U. S. Steel Corp., with his model of a loose housing system, and W. O. Zervas, American Iron and Steel Institute, with one on galvanized steel sheets for roofing and siding, won ribbons in the industrial class for demonstration models.

PERSONNEL SERVICE BULLETIN

Note: In this bulletin the following listings current and previously reported are not repeated in detail; for further information see the issue of AGRICULTURAL ENGINEERING indicated. "Agricultural Engineer" as used in these listings is not intended to imply any specific level of proficiency or registration as a professional engineer. Items published herein are summaries of mimeographed listings carried in the Personnel Service, copies of which will be furnished on request. To be listed in this Bulletin, request form for Personnel Service listings.

Positions Open — February O-13-901. **March** — O-39-904, 41-905. **April** — O-55-909, 58-910, 56-911, 59-912. **May** — O-77-914, 49-915, 97-919. **June** — O-124-920, 131-922, 132-923, 111-924, 135-926, 136-927, 137-928, 149-929, 140-930. **July**—O-170-931, 177-932, 186-933. **August**—O-214-935, 215-936, 216-937, 217-938, 218-939, 212-940, 220-941, 223-942, 228-943, 228-944, 231-946, 231-947, 231-948, 247-949, 259-950, 259-951.

Positions Wanted — January — W-355-67, 383-68, 411-69, 412-70, 406-71, 419-72, 422-73. **February**—W-9-1, 22-3, 23-4, 20-5. **March** — W-25-6, 33-9, 30-10. **April** — W-54-11, 70-12, 72-13. **May** — W-83-15, 84-16, 98-20, 100-22. **June** — W-103-25, 104-26, 118-27, 112-28, 123-29. **July** — W-154-31, 178-32, 196-33, 190-34. **August** — W-199-35, 210-36, 224-37, 213-38.

NEW POSITIONS OPEN

Agricultural Engineer for design and development of farm building plans and to provide technical help to farm building fabricators, with building materials manufacturer. Midwest. Age 25-35. BS, with primary interest in farm structures. Farm background and several years experience in farm structures field. Able to work with engineers and farmers. Excellent opportunity in fast growing program. Salary open. O-265-952

Engineer for design of food processing equipment, with responsibility for development projects. Location southern Wisconsin or northern Illinois. Small city near Wisconsin vacationland. BSAE, BSME, or equivalent. Should have present classification as project engineer or equivalent, and enough experience to handle projects from inception to completion. Prefer married man with good health, creative, and able to guide and get along with people. Excellent opportunity in expanding company with policy of promoting from within. Salary open. O-234-953

Agricultural Engineer for teaching and research in any phase of agricultural engineering in Puerto Rico. Age under 45. MSAE required, Ph.D. desirable. Some teaching and/or research experience preferred. Usual personal qualifications for college teaching and research. Knowledge of Spanish not required, but interest in the language desirable. Good opportunity for advancement. Salary open. O-219-954

Territory Manager for sale of specialized items to farm equipment dealers and elevators. Midwestern state territory. Age 30-50. College education desirable. Sales experience and training. Proven ability to sell successfully and to represent employer with honesty and integrity. Knowledge of farming and farm machinery desirable. Excellent business opportunity, with possibility of earned advancement to management position. Salary based on experience, with travel allowance and bonus arrangement. O-264-955

Agricultural Engineer to head crop dryer department of established farm equipment manufacturer in Midwest. Work will include research, design, sales assistance, and contacting agricultural colleges. Age 50 or less. BSAE or BSME, with prior experience in drying. Able to guide, instruct, and get along with others. Excellent opportunities for advancement. Salary open. O-275-956

Junior Product Engineer for development, improvement, field testing and preparation for production of farm machinery, including forage harvesters and other feed handling and processing equipment, with established manufacturer in East. Age 22-30. BSAE, BSME, or equivalent. Livestock farm background. Familiar with use of farm machinery. Engineering experience in farm equipment desirable. Intelligence, good health, and ability to work with factory, office and farm personnel. Good opportunity with expanding department of reliable company in desirable location. Salary open. Bonus and other benefits. O-285-957

Agricultural Engineer for design and development with established manufacturer of agricultural sprayers and related equipment. Experience 3 or more years with latest methods of hydraulic and air-blast spraying. Good knowledge of aerodynamics and axial fan design work, with follow-through from design and field tests to final production. Favorable living conditions in pleasant, medium-sized eastern city with good schools and recreational facilities. Permanent position with growing company. Salary open, depending on training and experience. O-277-958

Agricultural Engineer for design and development staff of an established manufacturer of power lawn mowers and related equipment in commercial and home use sizes. Midwest. BSAE, BSME, or equivalent. Some experience in mechanical design and development. Usual personal qualifications for commercial engineering. Excellent opportunity for advancement. Salary open. O-286-959

NEW POSITIONS WANTED

Agricultural Engineer for design, development, or research in soil and water field with manufacturer, distributor, or consultant, anywhere in USA. Married. Age 23. No disability. BSAE, 1958, University of Missouri. Experience in testing soil percolation, 6 months. Commissioned service in Navy 2 years. Boiler officer on aircraft carrier, in charge of boilers, fuel, water, and 200 men. Available February 1960. Salary open. W-249-40

Agricultural Engineer for teaching or research in power and machinery, rural electric or product processing field with industry or public service, anywhere in USA. Single. Age 28. No disability. B Tech in Agr. Engr., Indian Institute of Technology. MSAE, Virginia Polytechnic Institute. Graduate assistant about one year. Available on reasonable notice. Salary open. W-258-41

Agricultural Engineer for teaching or research in farm structures with industry or public service, anywhere in USA. Married. Age 33. BSAE, 1951, South Dakota State College. MSCE, 1959, University of Illinois. Farm background. Instructor 18 months in veterans on-the-farm training. General construction 4 years, with practical experience in all building trades. Teaching and research in agricultural engineering Kansas State College, one year. Navy electronics school 11 months. Available on reasonable notice. Salary $7,000 min. W-244-42

Farm Service Advisor for sales work in electric power and processing field with manufacturer, distributor, or trade association, anywhere in USA. Married. Age 38. No disability. BSA, 1949, Western Kentucky State College. War non-commissioned service 3 years, in Army Signal Corps, with promotions to M/Sgt. Head fieldman with milk company 4 years. Farm service advisor, REA Co-Op, 4 years. Available on reasonable notice. Salary $8,000. W-245-43

Agricultural Engineer for design, development or research in farm structures or environment control, with manufacturer or consultant, preferably in Northeast. Married. Age 27. No disability. BSAE, 1955, Iowa State College. Farm structures option. Additional night school courses in reinforced concrete and indeterminate structures, Fenn College, 1959. Farm background. Summer vacation work as general carpenter for farm buildings contractor. Military service over 2 years as jet pilot in USAF. Over one year as bridge designer — detailer for consulting engineering firm. Available on one month notice. Salary $490 per month. W-267-44

Agricultural soils man for design, development or research in soil and water field with Federal agency or manufacturer in South, Midwest, or Hawaii. Married. Age 25. No disability. BS in agricultural science, 1956, University of Wisconsin. Experience in operation of own farm, and own landscaping business, and as apprentice to general contractor. Navy service over 2 years as radarman. Available on reasonable notice. Salary open. W-269-45

Agricultural Engineer for design, development, extension, sales, service, or writing in power and machinery, farm structures, soil and water, or materials handling with industry or public service, in Northeast, Midwest or West. Married. Age 31. No disability. BSAE, 1953, University of Maine. Farm background. Farm equipment sales, 8 months. Extension, with some design and writing in farm structures field, 16 months. Field test and writing on forage harvesting equipment, 16 months. Design and supervisory experience on soil and water control structures, 2 years. Non-commissioned service, USAF, photography, 3 years. Available on one month's notice. W-270-46

The following is a list of recent applicants for membership in the American Society of Agricultural Engineers. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Barefoot, Stanley O. — Civil engr., (SCS) USDA, P.O. Box 662, Kinston, N.C.

Bent, Russell E.—Design engr., Mill and Elevator Co. (Mail) 7712 Palm Dr., Des Moines 22, Iowa

Blewitt, Ronald I.—State conservation engr., (SCS) USDA, Room 202, Federal Building, Honolulu 16, Hawaii

Borgstrom, Georg A. — Professor, Food Science Laboratory, Michigan State University. (Mail) 904 Evergreen Ave., East Lansing, Mich.

Brehm, Clarence D.—State conservation engr., (SCS) USDA. (Mail) 1356 McDonald Dr., Huron, S. D.

Chu, Patrick—Graduate student, eng. science dept., Ontario Agricultural College, Guelph, Ont., Canada

Dyer, David R. — Eng. trainee, John Deere Waterloo Tractor Works. (Mail) 900½ W. Parker, Waterloo, Iowa

Eliyathamby, Herbert W.—Foreman, eng. div. workshops, Dept. of Agr., Gannorouwa, Peradeniya, Ceylon

George, Gerald O. — Agr. engr., (SCS) USDA. (Mail) Box 761, Madras, Ore.

Hamm, John J., Jr.—Agr. engr., Duke Power Co. (Mail) 2448 S. Alston Ave., Durham, N. C.

Hobbs, Wilbert F.—Instructor, agr. eng. dept., The Pennsylvania State University, University Park, Pa.

James, William T., Jr.—Eng. spec., (SCS) USDA. (Mail) 286 Richland Ave., Morgantown, W. Va.

Locke, Lorenza, W. — Pres. and mgr., Enfield Oil Co., Inc. (Mail) P.O. Box 95, Enfield, N. C.

Mulbar, Harmon A.—Public relations and adv. mgr., American Society of Agricultural Engineers, 420 Main St., St. Joseph, Mich.

Niemann, Jerrold L. — Engr., Farm Engineering Inc. (Mail) Box 225, Cokato, Minn.

Patterson, Russell J. — Student, Michigan State University. (Mail) 1608 W. Mt. Hope, Lansing 10, Mich.

Romer, James C.—Owner, Romer Agr. Engineers, Holly, Colo.

Schmidt, Robert L. — Design engr. trainee, John Deere Industrial Equipment Works, Moline, Ill.

Schultz, Herbert B.—Spec. and lecturer, agr. eng. dept., University of California, Davis. Calif.

Smith, Horace A. — Marketing spec., North Carolina Dept. of Agr., Agr. Bldg., Raleigh, N. C.

Tyndall, Lloyd A.—Agr. engr., (SCS) USDA. (Mail) Box 928, Kinston, N. C.

von Pogrell, Hubertus — Exchange student, agr. eng. dept., Michigan State University from University of Bonn, Germany. (Mail) Erloserkirchweg 14, Koln-Rath, West Germany

Williams, Joseph H. — Proj. engr., (SCS) USDA. (Mail) Box 928, Kinston, N.C.

TRANSFER OF MEMBERSHIP

Butler, Herbert E. — Sales engr., Louisiana Agr. Co-op., Inc. (Mail) 9545 Cal Rd., Baton Rouge 8, La. (Associate Member to Member)

Fogel, Martin M.—Ext. irrigation spec., agr. eng. dept., South Dakota State College, College Station, Brookings, S. D. (Associate Member to Member)

Goss, John R.—Asst. agr. engr., agr. eng. dept., University of California, Davis, Calif. (Associate Member to Member)

Moore, David S. — Sr. hydraulic engr., California Districts Securities Commission. (Mail) 2186 Novato Blvd., Novato, Calif. (Associate Member to Member)

Smerdon, Ernest T.—Assoc. prof. in agr. eng., agr. eng. dept., Texas A. & M. College, College Station, Texas (Associate Member to Member)

Thompson, Gene T. — Agr. engr., Irrigation Inc. (Mail) Box 1474, Quincy, Wash. (Associate Member to Member)

STUDENT MEMBER TRANSFERS

Adkins, S. Wayne—(University of Georgia). (Mail) R.R. 1, Vienna, Ga.

Bullard, David E. — Ohio State University, Baker Hall-Campus, Columbus, Ohio

Colbert, R. Michael — (University of New Hampshire). (Mail) Lull Rd., New Boston, N. H.

Hix, Larry B. — (University of Georgia). (Mail) R.R. 4, Commerce, Ga.

Landphair, Donald R.—(Iowa State College). (Mail) Pleasanton, Iowa

Love, Herschel D., Jr.—(Alabama Polytechnic Institute). (Mail) 112 N. Sixth St., Opelina, Ala.

Miller, John H.—(Pennsylvania State University). (Mail) R.R. 1, Clarion, Pa.

Shown, Frank S.—(University of Arizona). (Mail) 4138 N. 48th Ave., Glendale, Ariz.

Shrivastava, Raghunandan — (University of Allahabad, India). (Mail) Government College of Agr., Jabalpur, M. P., India

Whitney, Jodie D.—(A. and M. College of Texas). (Mail) R.R. 2, Valley Mills, Tex.

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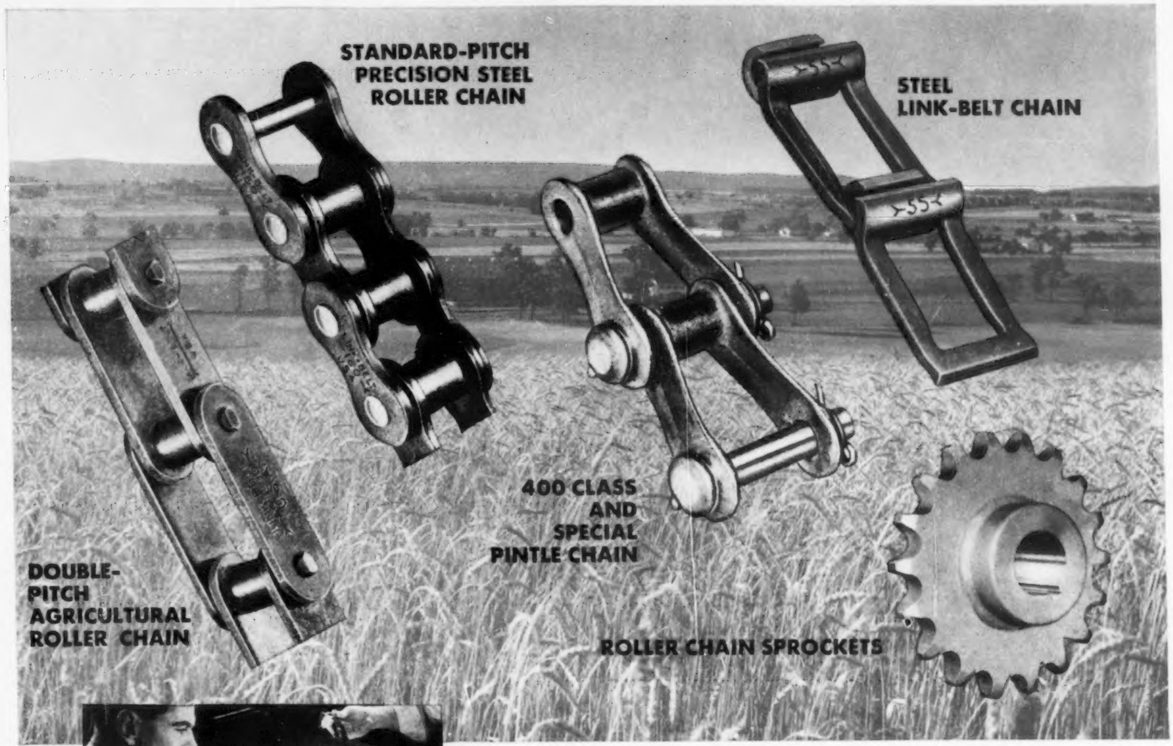
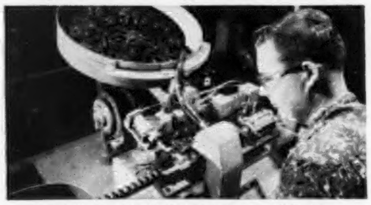
How LINK-BELT'S broad chain selection aids the designer, improves the design



EXPERT ENGINEERING—Link-Belt maintains an engineering staff of unsurpassed experience in the application of chain.



ACCURATE MANUFACTURE — Modern, specialized machines give economies of large-scale mass production, yet maintain high accuracy.

A COMPLETE LINE assures correct selection for each job. This Case No. 135 manure spreader uses Link-Belt steel detachable chains on apron conveyor.

LINK-BELT builds a complete line of chains, chain attachments and sprockets . . . to top farm machine standards, to match your needs

With Link-Belt's broad line of chains and chain attachments, designers of farm machinery are sure to get the *one* chain that's best for each application. Horsepower, loading, speed, impact—every requirement can be met to enable your machine to maintain rated performance and efficiency.

Yes, Link-Belt's unmatched facilities, services and experience (over 300 farm machinery manufacturers rely on Link-Belt) are your best assurance of quality products, properly applied. Next time you're considering a drive or conveyor application, our specialists will be glad to work with you. For facts and prompt service, call your nearby Link-Belt office or write our Indianapolis plant at 220 S. Belmont Ave.

640-Page Catalog 1050 has complete information on all Link-Belt chains. Other Link-Belt components for power transmission and materials handling are also detailed. Write for your copy.

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